KINEMATICS

MAY/JUNE2012 9709/41

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 $v\ \mathrm{m\,s^{-1}}$, 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]

(i) 8
(ii) 108

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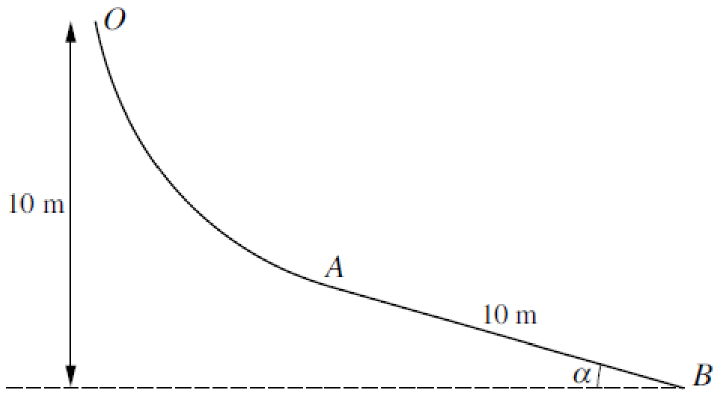

The diagram shows the vertical cross-section OAB of a slide. The straight line AB is tangential to the curve OA at A. The line AB is inclined at α to the horizontal, where $\sin\alpha = 0.28$. The point O is 10 m higher than B, and AB has length 10 m (see diagram). The part of the slide containing the 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]

(i) 12
(ii) 2
(iii) 13.6

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A particle P moves in a straight line, starting from the point O with velocity $2\,\text{m s}^{-1}$. 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 $3\,\text{m s}^{-1}$. [4]

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

(ii) 2.13

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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 m s^{-1} at time t 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 m at time t 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]

(i) v(approach) = 1.4, v(return) = -1, t = 3.25

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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 s after leaving O is v 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]

(i) 22.5
(ii) 4

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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 s and speed v 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 W, and the resistance to the car's motion is constant and equal to R 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]

(i) 4, 0.244
(ii) P = 30800, R = 1240

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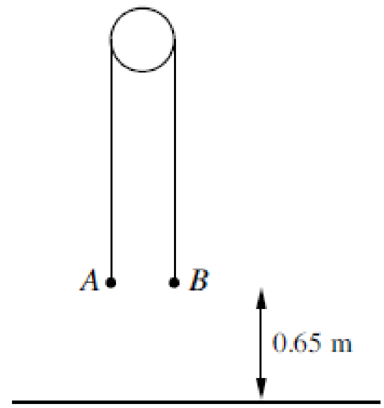

Two particles A and B have masses 0.12 kg and 0.38 kg respectively. The particles are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. A is held at rest with the string taut and both straight parts of the string vertical. A and B are each at a height of 0.65 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 s.

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

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

(i) 5.2
(ii) 2.6, 0,5
(iii) 1.02
(iv) 1.326

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

(ii) 16.9
(iii) 1070
(iv) 144

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A particle P moves in a straight line. It starts from a point O on the line with velocity $1.8\,\mathrm{m\,s^{-1}}$. The acceleration of P at time t s after leaving O is $0.8t^{-0.75}\,\mathrm{m\,s^{-2}}$. Find the displacement of P from O when $t = 16$. [6]

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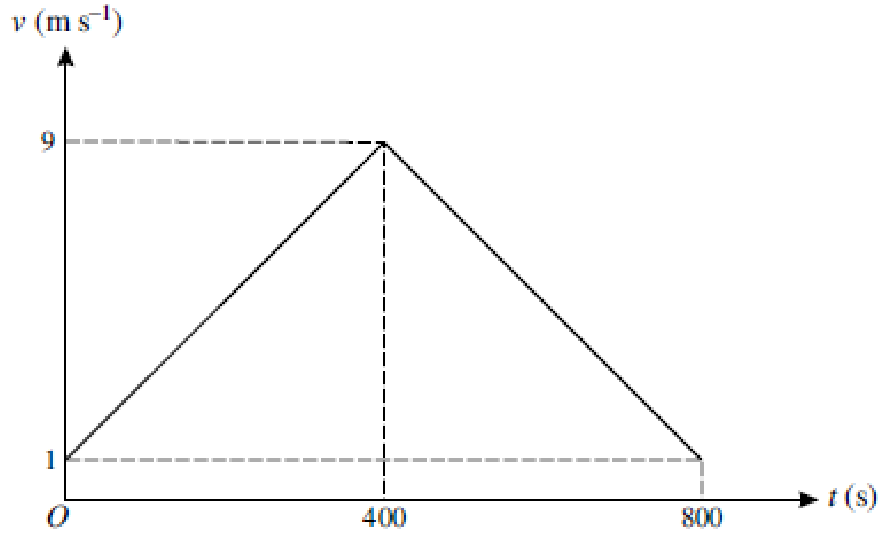
A tractor travels in a straight line from a point A to a point B. The velocity of the tractor is $v\,\mathrm{m\,s^{-1}}$ at time t s after leaving A.

(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 $0 \leqslant t \leqslant 800$.

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

(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 $-1 \leqslant v_1 - v \leqslant 1$. [2]

(i) (a) 4000
(b) 0.02, -0.02
(ii) (a) 200, 600

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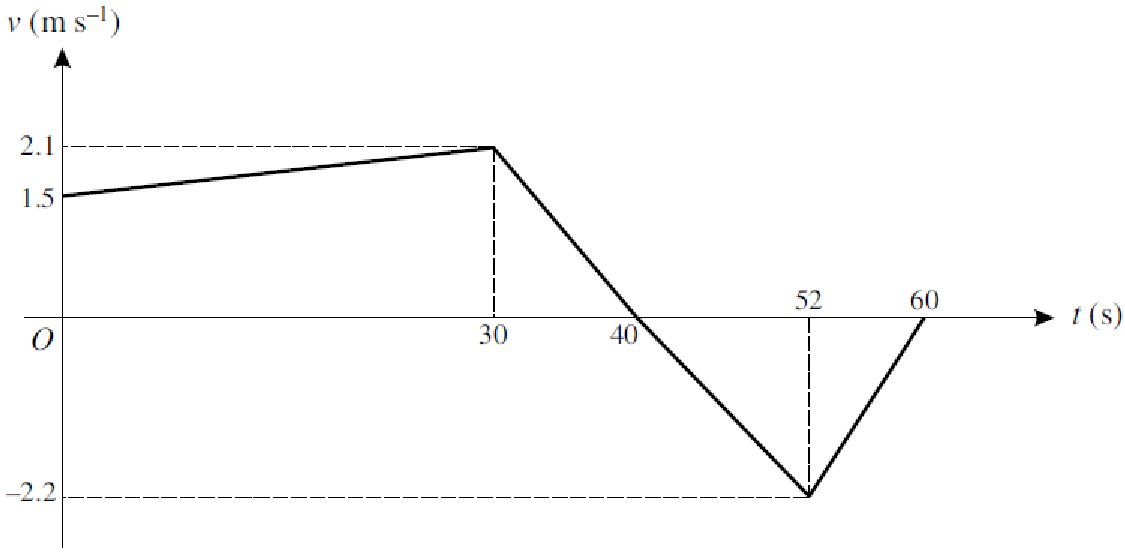

A woman walks in a straight line. The woman's velocity t seconds after passing through a fixed point A on the line is $v \text{ m s}^{-1}$. The graph of v against t consists of 4 straight line segments (see diagram). The woman is at the point B when $t = 60$. Find

(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]

(i) 0.02, -0.21
(ii) 42.5
(iii) 86.5

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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 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]

(i) $2t^3 - kt^4/4$
(ii) t=6/k
(iii) 1
(iv) 32

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A train starts from rest at a station A and travels in a straight line to station B, where it comes to rest. The train moves with constant acceleration 0.025 m s^{-2} for the first 600 s, with constant speed for the next 2600 s, and finally with constant deceleration 0.0375 m s^{-2}.

(i) Find the total time taken for the train to travel from A to B. [4]

(ii) Sketch the velocity-time graph for the journey and find the distance AB. [3]

(iii) The speed of the train t seconds after leaving A is 7.5 m s^{-1}. State the possible values of t. [1]

(i) 3600
(ii) 46500
(iii) 300, 3400

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A particle travels in a straight line from a point P to a point Q. Its velocity t seconds after leaving P is $v\,\mathrm{m\,s^{-1}}$, where $v = 4t - \frac{1}{16}t^3$. The distance PQ is 64 m.

(i) Find the time taken for the particle to travel from P to Q. [5]

(ii) Find the set of values of t for which the acceleration of the particle is positive. [4]

(i) 8

(ii) $0 < t < 4.62$

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Two particles P and Q are projected vertically upwards from horizontal ground at the same instant. The speeds of projection of P and Q are $12\,\mathrm{m\,s^{-1}}$ and $7\,\mathrm{m\,s^{-1}}$ respectively and the heights of P and Q above the ground, t seconds after projection, are h_P m and h_Q m respectively. Each particle comes to rest on returning to the ground.

(i) Find the set of values of t for which the particles are travelling in opposite directions. [3]

(ii) At a certain instant, P and Q are above the ground and $3h_P = 8h_Q$. Find the velocities of P and Q at this instant. [5]

(i) $0.7 < t < 1.2$

(ii) 4, -1

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A walker travels along a straight road passing through the points A and B on the road with speeds $0.9\,\text{m}\,\text{s}^{-1}$ and $1.3\,\text{m}\,\text{s}^{-1}$ respectively. The walker's acceleration between A and B is constant and equal to $0.004\,\text{m}\,\text{s}^{-2}$.

(i) Find the time taken by the walker to travel from A to B, and find the distance AB. [3]

A cyclist leaves A at the same instant as the walker. She starts from rest and travels along the straight road, passing through B at the same instant as the walker. At time t s after leaving A the cyclist's speed is $kt^3\,\text{m}\,\text{s}^{-1}$, where k is a constant.

(ii) Show that when $t = 64.05$ the speed of the walker and the speed of the cyclist are the same, correct to 3 significant figures. [5]

(ii) Find the cyclist's acceleration at the instant she passes through B. [2]

(i) 100, 110
(ii) both are 1.16
(iii) 0.132

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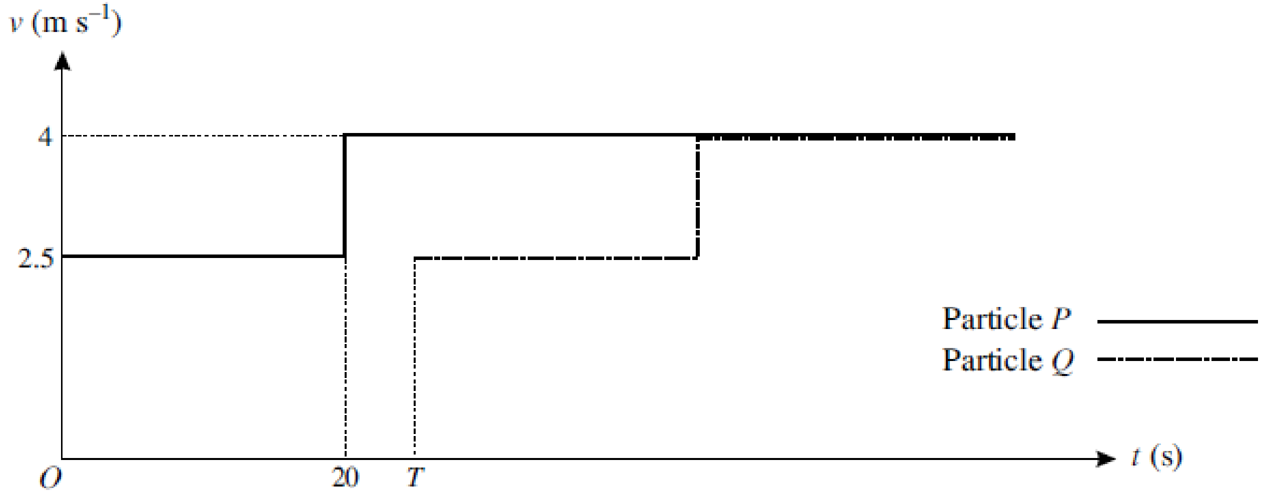

The diagram shows the velocity-time graphs for the motion of two particles P and Q, which travel in the same direction along a straight line. P and Q both start at the same point X on the line, but Q starts to move T s later than P. Each particle moves with speed $2.5\,\text{m s}^{-1}$ for the first 20 s of its motion. The speed of each particle changes instantaneously to $4\,\text{m s}^{-1}$ after it has been moving for 20 s and the particle continues at this speed.

(i) Make a rough copy of the diagram and shade the region whose area represents the displacement of P from X at the instant when Q starts. [1]

It is given that P has travelled 70 m at the instant when Q starts.

(ii) Find the value of T. [2]

(iii) Find the distance between P and Q when Q's speed reaches $4\,\text{m s}^{-1}$. [2]

(iv) Sketch a single diagram showing the displacement-time graphs for both P and Q, with values shown on the t-axis at which the speed of either particle changes. [2]

(ii) 25
(iii) 100

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A particle travels in a straight line from A to B in 20 s. Its acceleration t seconds after leaving A is a m s^{-2}, where $a = \frac{3}{160}t^2 - \frac{1}{800}t^3$. It is given that the particle comes to rest at B.

(i) Show that the initial speed of the particle is zero. [4]

(ii) Find the maximum speed of the particle. [2]

(iii) Find the distance AB. [4]

(ii) 5.27
(iii) 50

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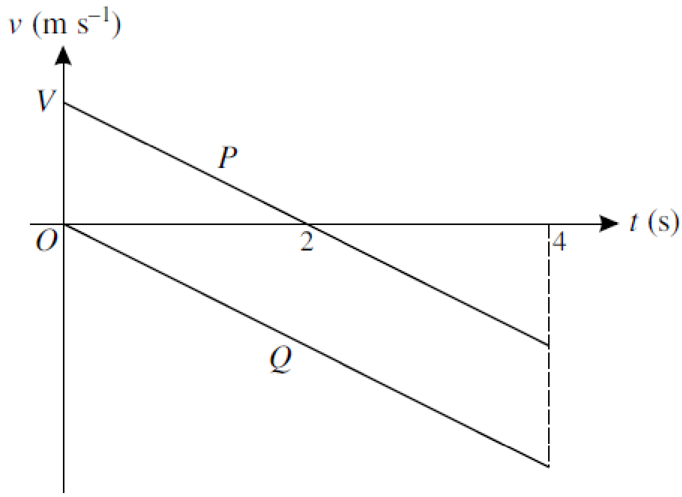

Two particles P and Q move vertically under gravity. The graphs show the upward velocity v m s^{-1} of the particles at time t s, for $0 \leqslant t \leqslant 4$. P starts with velocity V m s^{-1} and Q starts from rest.

(i) Find the value of V. [2]

Given that Q reaches the horizontal ground when $t = 4$, find

(ii) the speed with which Q reaches the ground, [1]

(iii) the height of Q above the ground when $t = 0$. [2]

(i) 20
(ii) 40
(iii) 80

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A particle P starts from a fixed point O at time $t = 0$, where t is in seconds, and moves with constant acceleration in a straight line. The initial velocity of P is $1.5\,\mathrm{m\,s^{-1}}$ and its velocity when $t = 10$ is $3.5\,\mathrm{m\,s^{-1}}$.

(i) Find the displacement of P from O when $t = 10$. [2]

Another particle Q also starts from O when $t = 0$ and moves along the same straight line as P. The acceleration of Q at time t is $0.03t\,\mathrm{m\,s^{-2}}$.

(ii) Given that Q has the same velocity as P when $t = 10$, show that it also has the same displacement from O as P when $t = 10$. [5]

(i) 25
(ii) 25m, same as P.

OCTOBER/NOVEMBER2010 9709/42

Particles P and Q are projected vertically upwards, from different points on horizontal ground, with velocities of $20\,\mathrm{m\,s^{-1}}$ and $25\,\mathrm{m\,s^{-1}}$ respectively. Q is projected 0.4 s later than P. Find

(i) the time for which P's height above the ground is greater than 15 m, [3]

(ii) the velocities of P and Q at the instant when the particles are at the same height. [5]

(i) Duration is 2s. (accept $1 < t < 3$)
(ii) 8, 17

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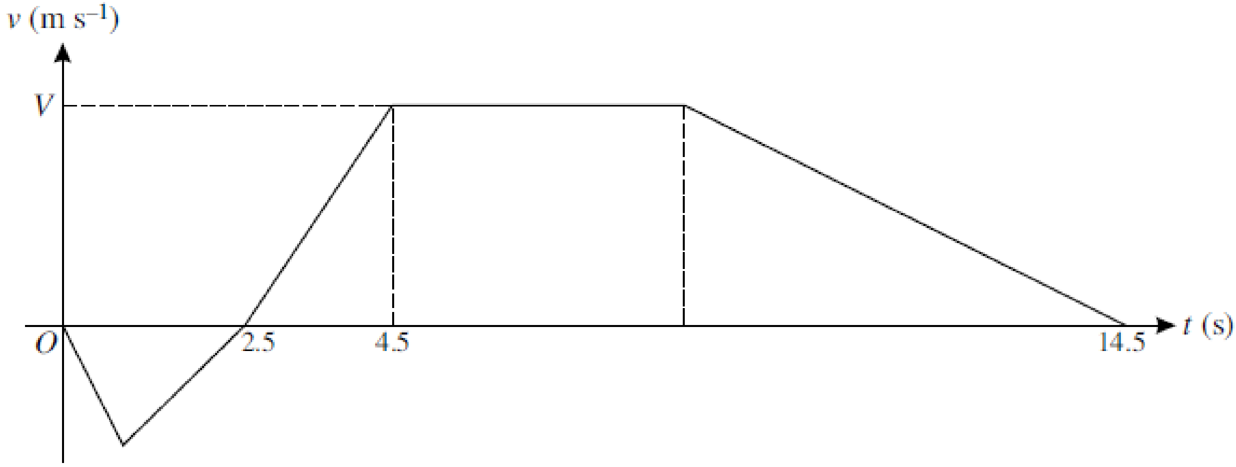

The diagram shows the velocity-time graph for a particle P which travels on a straight line AB, where $v\,\mathrm{m\,s^{-1}}$ is the velocity of P at time t s. The graph consists of five straight line segments. The particle starts from rest when $t = 0$ at a point X on the line between A and B and moves towards A. The particle comes to rest at A when $t = 2.5$.

(i) Given that the distance XA is 4 m, find the greatest speed reached by P during this stage of the motion. [2]

In the second stage, P starts from rest at A when $t = 2.5$ and moves towards B. The distance AB is 48 m. The particle takes 12 s to travel from A to B and comes to rest at B. For the first 2 s of this stage P accelerates at $3\,\mathrm{m\,s^{-2}}$, reaching a velocity of $V\,\mathrm{m\,s^{-1}}$. Find

(ii) the value of V, [2]

(iii) the value of t at which P starts to decelerate during this stage, [3]

(iv) the deceleration of P immediately before it reaches B. [2]

(i) 3.2
(ii) 6
(iii) 8.5
(iv) 1

OCTOBER/NOVEMBER2010 9709/42

A particle P travels in a straight line. It passes through the point O of the line with velocity $5\,\mathrm{m\,s^{-1}}$ at time $t = 0$, where t is in seconds. P's velocity after leaving O is given by

$$(0.002t^3 - 0.12t^2 + 1.8t + 5)\,\mathrm{m\,s^{-1}}.$$

The velocity of P is increasing when $0 < t < T_1$ and when $t > T_2$, and the velocity of P is decreasing when $T_1 < t < T_2$.

(i) Find the values of T_1 and T_2 and the distance OP when $t = T_2$. [7]

(ii) Find the velocity of P when $t = T_2$ and sketch the velocity-time graph for the motion of P. [3]

(i) T1 = 10, T2 = 30, 285
(ii) 5

OCTOBER/NOVEMBER2010 9709/43

A particle starts from rest at a point X and moves in a straight line until, 60 seconds later, it reaches a point Y. At time t s after leaving X, the acceleration of the particle is

$$\begin{aligned} 0.75\,\mathrm{m\,s^{-2}} &\quad \text{for} \quad 0 < t < 4, \\ 0\,\mathrm{m\,s^{-2}} &\quad \text{for} \quad 4 < t < 54, \\ -0.5\,\mathrm{m\,s^{-2}} &\quad \text{for} \quad 54 < t < 60. \end{aligned}$$

(i) Find the velocity of the particle when $t = 4$ and when $t = 60$, and sketch the velocity-time graph. [5]

(ii) Find the distance XY. [2]

(i) 3, 0
(ii) 165

OCTOBER/NOVEMBER2010 9709/43

A particle travels along a straight line. It starts from rest at a point A on the line and comes to rest again, 10 seconds later, at another point B on the line. The velocity t seconds after leaving A is

$$\begin{aligned} 0.72t^2 - 0.096t^3 &\quad \text{for} \quad 0 \leqslant t \leqslant 5, \\ 2.4t - 0.24t^2 &\quad \text{for} \quad 5 \leqslant t \leqslant 10. \end{aligned}$$

(i) Show that there is no instantaneous change in the acceleration of the particle when $t = 5$. [4]

(ii) Find the distance AB. [4]

(i) a1 = a2 = 0
(ii) 35

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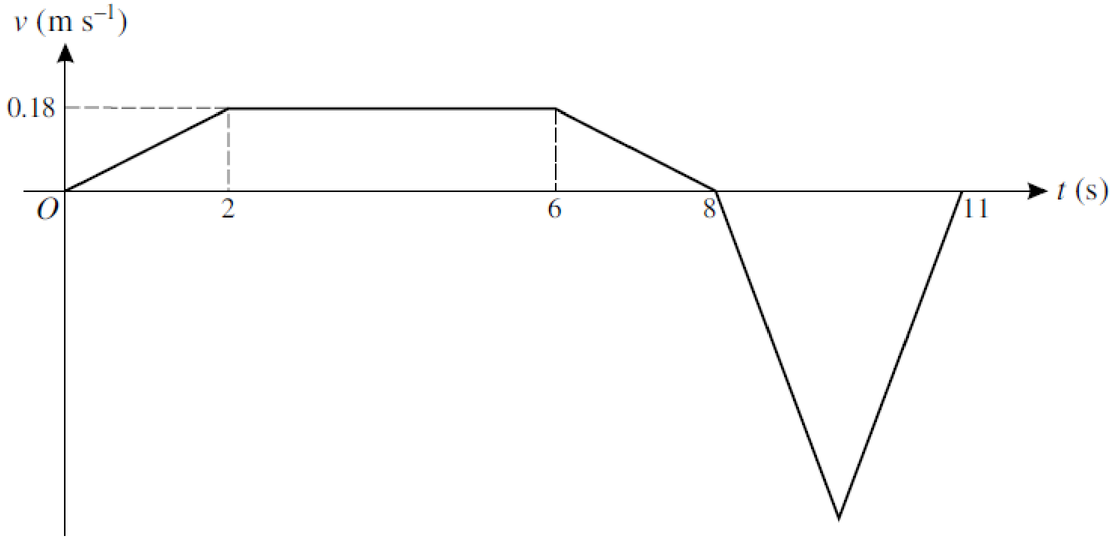


The diagram shows the velocity-time graph for the motion of a machine's cutting tool. The graph consists of five straight line segments. The tool moves forward for 8 s while cutting and then takes 3 s to return to its starting position. Find

(i) the acceleration of the tool during the first 2 s of the motion, [1]

(ii) the distance the tool moves forward while cutting, [2]

(iii) the greatest speed of the tool during the return to its starting position. [2]

(i) 0.09
(ii) 1.08
(iii) 0.72

MAY/JUNE2010 9709/41

A vehicle is moving in a straight line. The velocity $v\,\mathrm{m\,s^{-1}}$ at time t s after the vehicle starts is given by

$$v = A(t - 0.05t^2) \quad \text{for } 0 \leqslant t \leqslant 15,$$
$$v = \frac{B}{t^2} \quad \text{for } t \geqslant 15,$$

where A and B are constants. The distance travelled by the vehicle between $t = 0$ and $t = 15$ is 225 m.

(i) Find the value of A and show that $B = 3375$. [5]

(ii) Find an expression in terms of t for the total distance travelled by the vehicle when $t \geqslant 15$. [3]

(iii) Find the speed of the vehicle when it has travelled a total distance of 315 m. [3]

(i) 4
(ii) $450 - 3375/t$
(iii) 5.4

MAY/JUNE2010 9709/43

A particle starts at a point O and moves along a straight line. Its velocity t s after leaving O is $(1.2t - 0.12t^2)$ m s^{-1}. Find the displacement of the particle from O when its acceleration is 0.6 m s^{-2}. [5]

3.125

MAY/JUNE2010 9709/43

A ball moves on the horizontal surface of a billiards table with deceleration of constant magnitude $d\,\mathrm{m\,s^{-2}}$. The ball starts at A with speed $1.4\,\mathrm{m\,s^{-1}}$ and reaches the edge of the table at B, 1.2 s later, with speed $1.1\,\mathrm{m\,s^{-1}}$.

(i) Find the distance AB and the value of d. [3]

AB is at right angles to the edge of the table containing B. The table has a low wall along each of its edges and the ball rebounds from the wall at B and moves directly towards A. The ball comes to rest at C where the distance BC is 2 m.

(ii) Find the speed with which the ball starts to move towards A and the time taken for the ball to travel from B to C. [3]

(iii) Sketch a velocity-time graph for the motion of the ball, from the time the ball leaves A until it comes to rest at C, showing on the axes the values of the velocity and the time when the ball is at A, at B and at C. [2]

(i) AB = 1.5, d = 0.25
(ii) v = 1, t = 4

OCTOBER/NOVEMBER2009 9709/41

A particle P starts from rest at the point A at time $t = 0$, where t is in seconds, and moves in a straight line with constant acceleration $a\ \mathrm{m\,s^{-2}}$ for 10 s. For $10 \leqslant t \leqslant 20$, P continues to move along the line with velocity $v\ \mathrm{m\,s^{-1}}$, where $v = \dfrac{800}{t^2} - 2$. Find

(i) the speed of P when $t = 10$, and the value of a, [2]

(ii) the value of t for which the acceleration of P is $-a\ \mathrm{m\,s^{-2}}$, [4]

(iii) the displacement of P from A when $t = 20$. [6]

(i) 6, 0.6
(ii) 13.9
(iii) 50

OCTOBER/NOVEMBER2009 9709/42

A motorcyclist starts from rest at A and travels in a straight line. For the first part of the motion, the motorcyclist's displacement x metres from A after t seconds is given by $x = 0.6t^2 - 0.004t^3$.

(i) Show that the motorcyclist's acceleration is zero when $t = 50$ and find the speed $V\ \mathrm{m\,s^{-1}}$ at this time. [5]

For $t \geqslant 50$, the motorcyclist travels at constant speed $V\ \mathrm{m\,s^{-1}}$.

(ii) Find the value of t for which the motorcyclist's average speed is $27.5\ \mathrm{m\,s^{-1}}$. [5]

(i) 30
(ii) 200

MAY/JUNE2009

A particle P travels in a straight line from A to D, passing through the points B and C. For the section AB the velocity of the particle is $(0.5t - 0.01t^2)$ m s^{-1}, where t s is the time after leaving A.

(i) Given that the acceleration of P at B is 0.1 m s^{-2}, find the time taken for P to travel from A to B. [3]

The acceleration of P from B to C is constant and equal to 0.1 m s^{-2}.

(ii) Given that P reaches C with speed 14 m s^{-1}, find the time taken for P to travel from B to C. [3]

P travels with constant deceleration 0.3 m s^{-2} from C to D. Given that the distance CD is 300 m, find

(iii) the speed with which P reaches D, [2]

(iv) the distance AD. [6]

(i) 20
(ii) 80
(iii) 4
(iv) 1170

OCTOBER/NOVEMBER2008

A train travels from A to B, a distance of 20 000 m, taking 1000 s. The journey has three stages. In the first stage the train starts from rest at A and accelerates uniformly until its speed is $V\ \mathrm{m\,s^{-1}}$. In the second stage the train travels at constant speed $V\ \mathrm{m\,s^{-1}}$ for 600 s. During the third stage of the journey the train decelerates uniformly, coming to rest at B.

(i) Sketch the velocity-time graph for the train's journey. [2]

(ii) Find the value of V. [3]

(iii) Given that the acceleration of the train during the first stage of the journey is $0.15\ \mathrm{m\,s^{-2}}$, find the distance travelled by the train during the third stage of the journey. [4]

(ii) 25
(iii) 2920

OCTOBER/NOVEMBER2008

A particle P is held at rest at a fixed point O and then released. P falls freely under gravity until it reaches the point A which is 1.25 m below O.

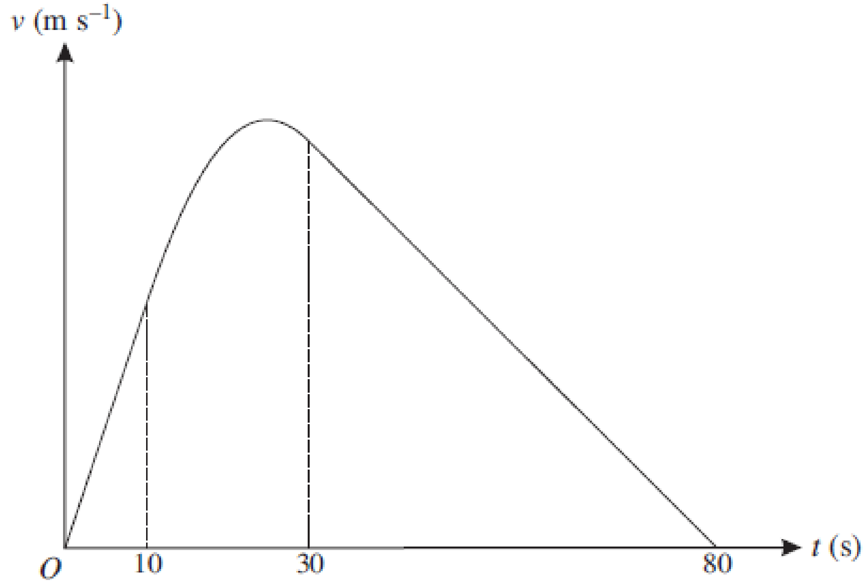
(i) Find the speed of P at A and the time taken for P to reach A. [3]

The particle continues to fall, but now its downward acceleration t seconds after passing through A is $(10 - 0.3t)\ \mathrm{m\,s^{-2}}$.

(ii) Find the total distance P has fallen, 3 s after being released from O. [7]

(i) 5, 0.5
(ii) 44.2

MAY/JUNE2008



An object P travels from A to B in a time of 80 s. The diagram shows the graph of v against t, where v m s^{-1} is the velocity of P at time t s after leaving A. The graph consists of straight line segments for the intervals $0 \leqslant t \leqslant 10$ and $30 \leqslant t \leqslant 80$, and a curved section whose equation is $v = -0.01t^2 + 0.5t - 1$ for $10 \leqslant t \leqslant 30$. Find

(i) the maximum velocity of P, [4]

(ii) the distance AB. [9]

(i) 5.25
(ii) 233

OCTOBER/NOVEMBER2007

A particle is projected vertically upwards from a point *O* with initial speed $12.5\,\text{m}\,\text{s}^{-1}$. At the same instant another particle is released from rest at a point 10 m vertically above *O*. Find the height above *O* at which the particles meet. [5]

6.8

OCTOBER/NOVEMBER2007

(i) A man walks in a straight line from A to B with constant acceleration $0.004\,\mathrm{m\,s^{-2}}$. His speed at A is $1.8\,\mathrm{m\,s^{-1}}$ and his speed at B is $2.2\,\mathrm{m\,s^{-1}}$. Find the time taken for the man to walk from A to B, and find the distance AB. [3]

(ii) A woman cyclist leaves A at the same instant as the man. She starts from rest and travels in a straight line to B, reaching B at the same instant as the man. At time t s after leaving A the cyclist's speed is $k(200t - t^2)\,\mathrm{m\,s^{-1}}$, where k is a constant. Find

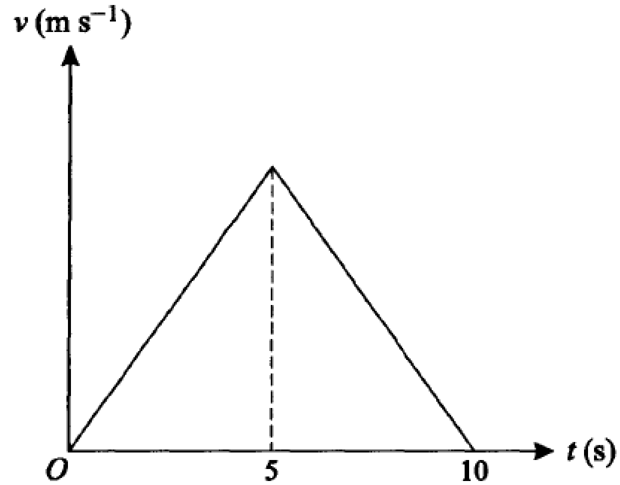
(a) the value of k, [4]

(b) the cyclist's speed at B. [1]

(iii) Sketch, using the same axes, the velocity-time graphs for the man's motion and the woman's motion from A to B. [3]

(i) t = 100, s = 200
(ii) (a) 0.0003
(b) 3

MAY/JUNE2007



A particle P starts from rest at the point A and travels in a straight line, coming to rest again after 10 s. The velocity-time graph for P consists of two straight line segments (see diagram). A particle Q starts from rest at A at the same instant as P and travels along the same straight line as P. The velocity of Q is given by $v = 3t - 0.3t^2$ for $0 \leqslant t \leqslant 10$. The displacements from A of P and Q are the same when $t = 10$.

(i) Show that the greatest velocity of P during its motion is 10 m s^{-1}. [6]

(ii) Find the value of t, in the interval $0 < t < 5$, for which the acceleration of Q is the same as the acceleration of P. [3]

(ii) 1.67

OCTOBER/NOVEMBER2006

The velocity of a particle t s after it starts from rest is $v\,\mathrm{m\,s^{-1}}$, where $v = 1.25t - 0.05t^2$. Find

(i) the initial acceleration of the particle, [2]

(ii) the displacement of the particle from its starting point at the instant when its acceleration is $0.05\,\mathrm{m\,s^{-2}}$. [5]

(i) 1.25
(ii) 61.2

MAY/JUNE2006

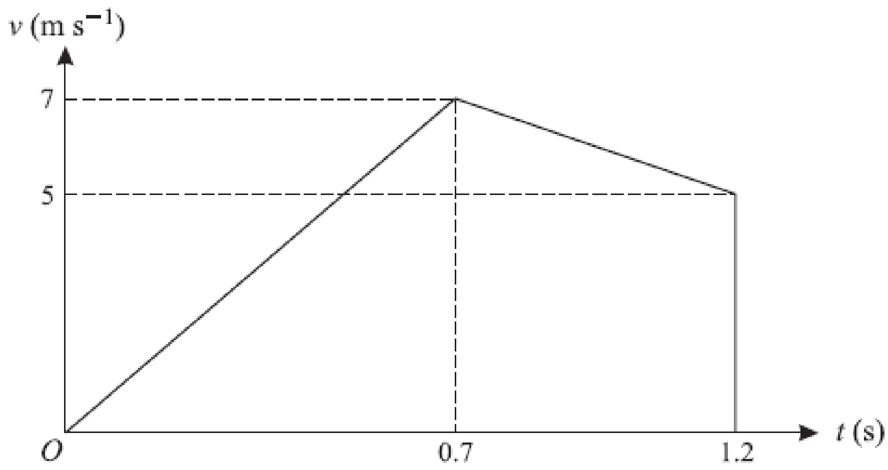
A motorcyclist starts from rest at A and travels in a straight line until he comes to rest again at B. The velocity of the motorcyclist t seconds after leaving A is $v\,\mathrm{m\,s^{-1}}$, where $v = t - 0.01t^2$. Find

(i) the time taken for the motorcyclist to travel from A to B, [2]

(ii) the distance AB. [3]

(i) 100
(ii) $1666\frac{2}{3}$

MAY/JUNE2006



The diagram shows the velocity-time graph for the motion of a small stone which falls vertically from rest at a point A above the surface of liquid in a container. The downward velocity of the stone t s after leaving A is v m s^{-1}. The stone hits the surface of the liquid with velocity 7 m s^{-1} when $t = 0.7$. It reaches the bottom of the container with velocity 5 m s^{-1} when $t = 1.2$.

(i) Find

(a) the height of A above the surface of the liquid,

(b) the depth of liquid in the container. [3]

(ii) Find the deceleration of the stone while it is moving in the liquid. [2]

(iii) Given that the resistance to motion of the stone while it is moving in the liquid has magnitude 0.7 N, find the mass of the stone. [3]

(i) (a) 2.45
(b) 3
(ii) 4
(iii) 0.05

OCTOBER/NOVEMBER2005

A car travels in a straight line with constant acceleration $a\,\mathrm{m\,s^{-2}}$. It passes the points A, B and C, in this order, with speeds $5\,\mathrm{m\,s^{-1}}$, $7\,\mathrm{m\,s^{-1}}$ and $8\,\mathrm{m\,s^{-1}}$ respectively. The distances AB and BC are d_1 m and d_2 m respectively.

(i) Write down an equation connecting

(a) d_1 and a,

(b) d_2 and a.

[2]

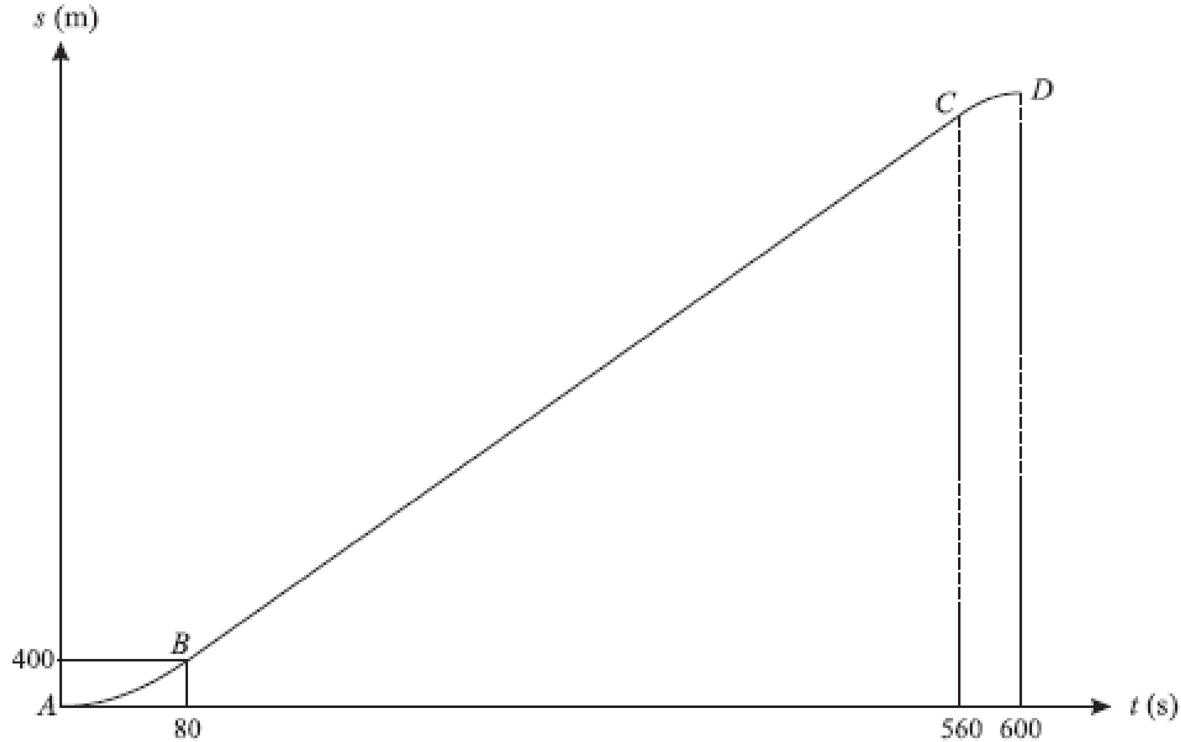
(ii) Hence find d_1 in terms of d_2. [2]

(i) (a) $24 = 2ad_1$

(b) $15 = 2ad_2$

(ii) $d_1 = 1.6d_1$

OCTOBER/NOVEMBER2005



The diagram shows the displacement-time graph for a car's journey. The graph consists of two curved parts AB and CD, and a straight line BC. The line BC is a tangent to the curve AB at B and a tangent to the curve CD at C. The gradient of the curves at $t = 0$ and $t = 600$ is zero, and the acceleration of the car is constant for $0 < t < 80$ and for $560 < t < 600$. The displacement of the car is 400 m when $t = 80$.

(i) Sketch the velocity-time graph for the journey. [3]

(ii) Find the velocity at $t = 80$. [2]

(iii) Find the total distance for the journey. [2]

(iv) Find the acceleration of the car for $0 < t < 80$. [2]

(ii) 10
(iii) 5400
(iv) 0.125

OCTOBER/NOVEMBER2005

A particle P starts from rest at O and travels in a straight line. Its velocity v m s^{-1} at time t s is given by $v = 8t - 2t^2$ for $0 \leqslant t \leqslant 3$, and $v = \frac{54}{t^2}$ for $t > 3$. Find

(i) the distance travelled by P in the first 3 seconds, [4]

(ii) an expression in terms of t for the displacement of P from O, valid for $t > 3$, [3]

(iii) the value of v when the displacement of P from O is 27 m. [3]

(i) 18
(ii) $36 - 54/t$
(iii) 1.5

MAY/JUNE2005

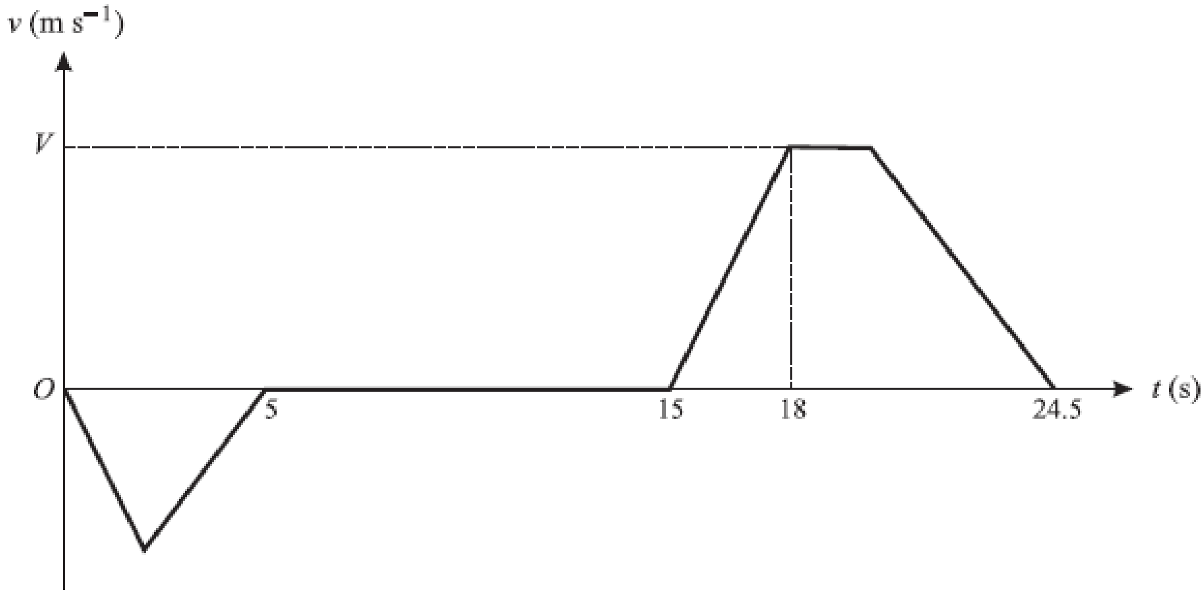
A particle P moves along the x-axis in the positive direction. The velocity of P at time t s is $0.03t^2$ m s^{-1}. When $t = 5$ the displacement of P from the origin O is 2.5 m.

(i) Find an expression, in terms of t, for the displacement of P from O. [4]

(ii) Find the velocity of P when its displacement from O is 11.25 m. [3]

(i) $0.01t^3 + 1.25$
(ii) 3

MAY/JUNE2005



The diagram shows the velocity-time graph for a lift moving between floors in a building. The graph consists of straight line segments. In the first stage the lift travels downwards from the ground floor for 5 s, coming to rest at the basement after travelling 10 m.

(i) Find the greatest speed reached during this stage. [2]

The second stage consists of a 10 s wait at the basement. In the third stage, the lift travels upwards until it comes to rest at a floor 34.5 m above the basement, arriving 24.5 s after the start of the first stage. The lift accelerates at 2 m s^{-2} for the first 3 s of the third stage, reaching a speed of V m s^{-1}. Find

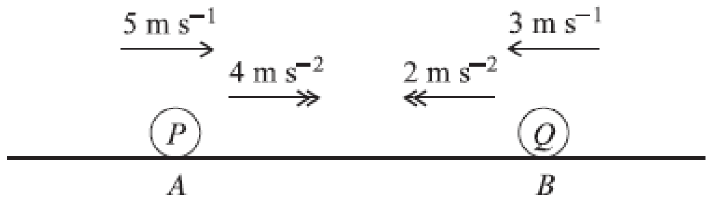
(ii) the value of V, [2]

(iii) the time during the third stage for which the lift is moving at constant speed, [3]

(iv) the deceleration of the lift in the final part of the third stage. [2]

(i) 4
(ii) 6
(iii) 2
(iv) $\frac{4}{3}$

OCTOBER/NOVEMBER2004



Particles P and Q start from points A and B respectively, at the same instant, and move towards each other in a horizontal straight line. The initial speeds of P and Q are 5 m s^{-1} and 3 m s^{-1} respectively. The accelerations of P and Q are constant and equal to 4 m s^{-2} and 2 m s^{-2} respectively (see diagram).

(i) Find the speed of P at the instant when the speed of P is 1.8 times the speed of Q. [4]

(ii) Given that $AB = 51$ m, find the time taken from the start until P and Q meet. [4]

(i) 9
(ii) 3

OCTOBER/NOVEMBER2004

A particle starts from rest at the point A and travels in a straight line until it reaches the point B. The velocity of the particle t seconds after leaving A is $v\,\mathrm{m\,s^{-1}}$, where $v = 0.009t^2 - 0.0001t^3$. Given that the velocity of the particle when it reaches B is zero, find

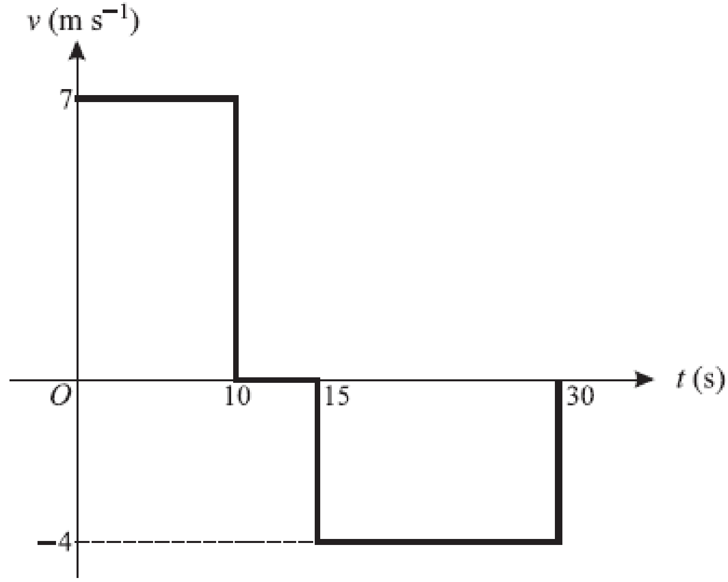
(i) the time taken for the particle to travel from A to B, [2]

(ii) the distance AB, [4]

(iii) the maximum velocity of the particle. [4]

(i) 90
(ii) 547
(iii) 10.8

MAY/JUNE2004



A boy runs from a point A to a point C. He pauses at C and then walks back towards A until reaching the point B, where he stops. The diagram shows the graph of v against t, where $v\,\mathrm{m\,s^{-1}}$ is the boy's velocity at time t seconds after leaving A. The boy runs and walks in the same straight line throughout.

(i) Find the distances AC and AB. [3]

(ii) Sketch the graph of x against t, where x metres is the boy's displacement from A. Show clearly the values of t and x when the boy arrives at C, when he leaves C, and when he arrives at B. [3]

(i) 70, 10

MAY/JUNE2004

A particle P moves in a straight line that passes through the origin O. The velocity of P at time t seconds is $v\ \mathrm{m\,s^{-1}}$, where $v = 20t - t^3$. At time $t = 0$ the particle is at rest at a point whose displacement from O is -36 m.

(i) Find an expression for the displacement of P from O in terms of t. [3]

(ii) Find the displacement of P from O when $t = 4$. [1]

(iii) Find the values of t for which the particle is at O. [3]

(i) $10t^2 - 0.25t^4 - 36$
(ii) 60
(iii) 2, 6

MAY/JUNE2004

A particle P_1 is projected vertically upwards, from horizontal ground, with a speed of $30\ \mathrm{m\,s^{-1}}$. At the same instant another particle P_2 is projected vertically upwards from the top of a tower of height 25 m, with a speed of $10\ \mathrm{m\,s^{-1}}$. Find

(i) the time for which P_1 is higher than the top of the tower, [3]

(ii) the velocities of the particles at the instant when the particles are at the same height, [5]

(iii) the time for which P_1 is higher than P_2 and is moving upwards. [3]

(i) 4 or $1 < t < 5$
(ii) 17.5, -2.5
(iii) 1.75 or $1.25 < t < 3$

OCTOBER/NOVEMBER2003

A stone is released from rest and falls freely under gravity. Find

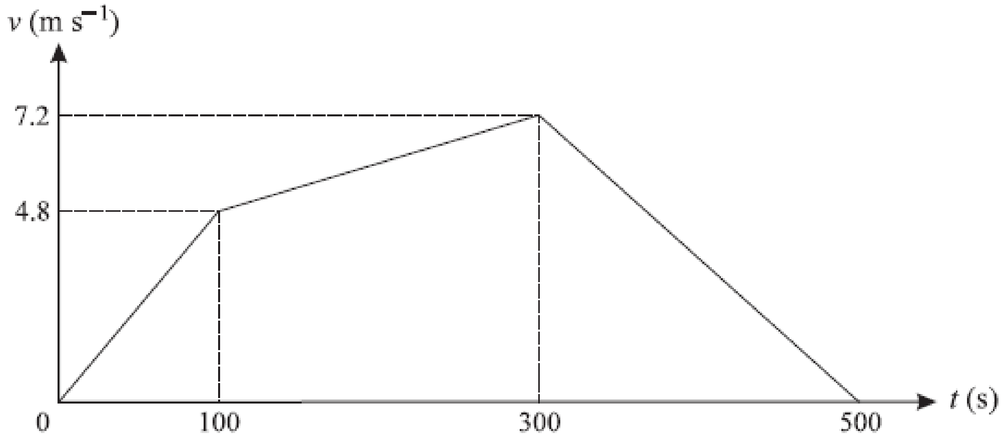
(i) the speed of the stone after 2 s, [1]

(ii) the time taken for the stone to fall a distance of 45 m from its initial position, [2]

(iii) the distance fallen by the stone from the instant when its speed is $30\,\mathrm{m\,s^{-1}}$ to the instant when its speed is $40\,\mathrm{m\,s^{-1}}$. [2]

(i) 20
(ii) 3
(iii) 35

OCTOBER/NOVEMBER2003



A tractor A starts from rest and travels along a straight road for 500 seconds. The velocity-time graph for the journey is shown above. This graph consists of three straight line segments. Find

(i) the distance travelled by A, [3]

(ii) the initial acceleration of A. [2]

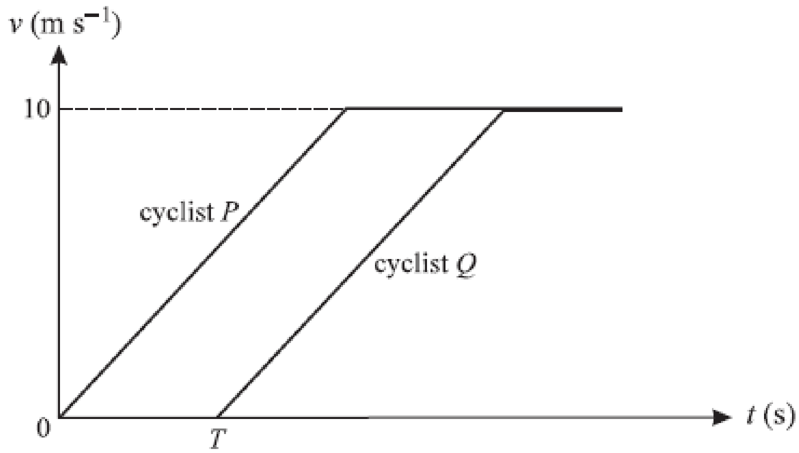
Another tractor B starts from rest at the same instant as A, and travels along the same road for 500 seconds. Its velocity t seconds after starting is $(0.06t - 0.00012t^2)\ \mathrm{m\,s^{-1}}$. Find

(iii) how much greater B's initial acceleration is than A's, [2]

(iv) how much further B has travelled than A, at the instant when B's velocity reaches its maximum. [6]

(i) 2160
(ii) 0.048
(iii) 0.012
(iv) 155

MAY/JUNE2003



The diagram shows the velocity-time graphs for the motion of two cyclists P and Q, who travel in the same direction along a straight path. Both cyclists start from rest at the same point O and both accelerate at $2\,\text{m s}^{-2}$ up to a speed of $10\,\text{m s}^{-1}$. Both then continue at a constant speed of $10\,\text{m s}^{-1}$. Q starts his journey T seconds after P.

(i) Show in a sketch of the diagram the region whose area represents the displacement of P, from O, at the instant when Q starts. [1]

Given that P has travelled 16 m at the instant when Q starts, find

(ii) the value of T, [3]

(iii) the distance between P and Q when Q's speed reaches $10\,\text{m s}^{-1}$. [2]

(ii) 4
(iii) 40

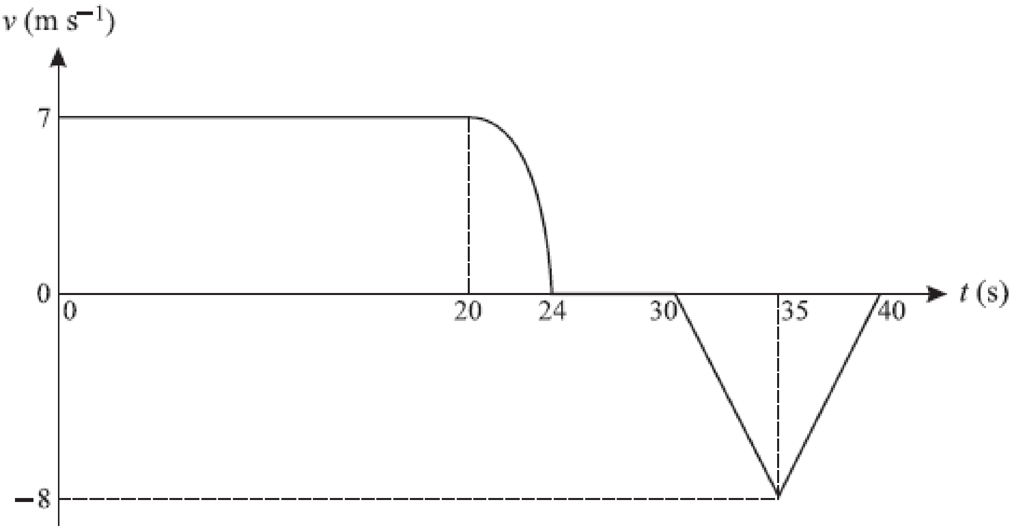
MAY/JUNE2003

A particle moves in a straight line. Its displacement t seconds after leaving the fixed point O is x metres, where $x = \frac{1}{2}t^2 + \frac{1}{30}t^3$. Find

(i) the speed of the particle when $t = 10$, [3]

(ii) the value of t for which the acceleration of the particle is twice its initial acceleration. [3]

(i) 20
(ii) 5



A man runs in a straight line. He passes through a fixed point A with constant velocity $7\ \mathrm{m\,s^{-1}}$ at time $t = 0$. At time t s his velocity is $v\ \mathrm{m\,s^{-1}}$. The diagram shows the graph of v against t for the period $0 \leqslant t \leqslant 40$.

(i) Show that the man runs more than 154 m in the first 24 s. [2]

(ii) Given that the man runs 20 m in the interval $20 \leqslant t \leqslant 24$, find how far he is from A when $t = 40$. [2]

(ii) 120

OCTOBER/NOVEMBER2002

Two particles A and B are projected vertically upwards from horizontal ground at the same instant. The speeds of projection of A and B are 5 m s^{-1} and 8 m s^{-1} respectively. Find

(i) the difference in the heights of A and B when A is at its maximum height, [4]

(ii) the height of A above the ground when B is 0.9 m above A. [4]

(i) 1.5
(ii) 1.05

OCTOBER/NOVEMBER2002

A particle P starts to move from a point O and travels in a straight line. At time t s after P starts to move its velocity is $v\,\mathrm{m\,s^{-1}}$, where $v = 0.12t - 0.0006t^2$.

(i) Verify that P comes to instantaneous rest when $t = 200$, and find the acceleration with which it starts to return towards O. [3]

(ii) Find the maximum speed of P for $0 \leqslant t \leqslant 200$. [3]

(iii) Find the displacement of P from O when $t = 200$. [3]

(iv) Find the value of t when P reaches O again. [2]

(i) 0.12
(ii) 6
(iii) 800
(iv) 300

MAY/JUNE2002

(i) A cyclist travels in a straight line from A to B with constant acceleration $0.06\,\mathrm{m\,s^{-2}}$. His speed at A is $3\,\mathrm{m\,s^{-1}}$ and his speed at B is $6\,\mathrm{m\,s^{-1}}$. Find

(a) the time taken by the cyclist to travel from A to B, [2]

(b) the distance AB. [2]

(ii) A car leaves A at the same instant as the cyclist. The car starts from rest and travels in a straight line to B. The car reaches B at the same instant as the cyclist. At time t s after leaving A the speed of the car is $kt^2\,\mathrm{m\,s^{-1}}$, where k is a constant. Find

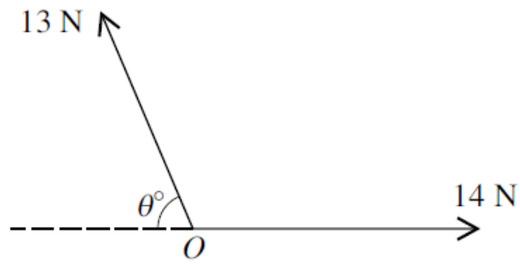
(a) the value of k, [4]

(b) the speed of the car at B. [1]

(i) (a) 50
(b) 225
(ii) (a) 0.0054
(b) 13.5

FORCES & EQUILIBRIUM

MAY/JUNE2012 9709/41



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]

(i) 67.4°
(ii) 9

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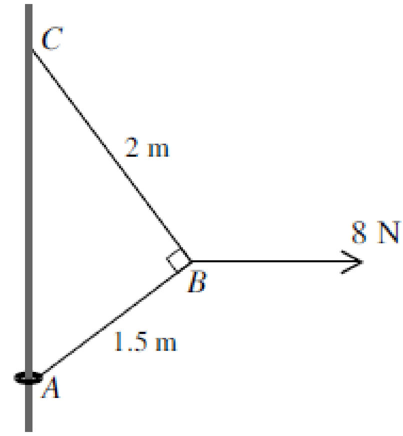

A small ring of mass 0.2 kg is threaded on a fixed vertical rod. The end A of a light inextensible string is attached to the ring. The other end C of the string is attached to a fixed point of the rod above A. A horizontal force of magnitude 8 N is applied to the point B of the string, where $AB = 1.5$ m and $BC = 2$ 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]

(i) T(AB) = 6.4, T(BC) = 4.8
(ii) 0.359

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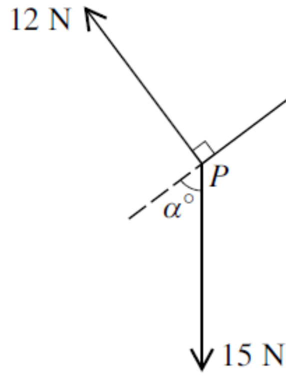
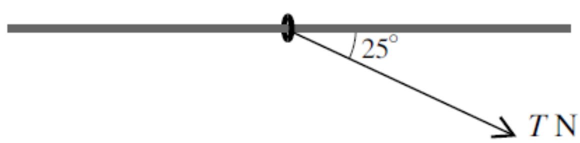


Three coplanar forces of magnitudes F N, 12 N and 15 N are in equilibrium acting at a point P in the directions shown in the diagram. Find α and F. [4]

53.1°, 9

MAY/JUNE2012 9709/42



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]

(i) Horizontal component = $T cos 25°$, Vertical component = $40 + 0.423T$
(ii) 21.7

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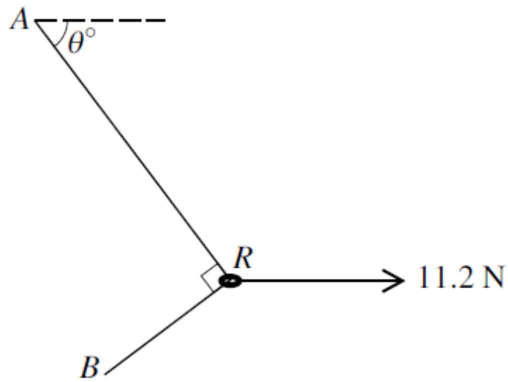
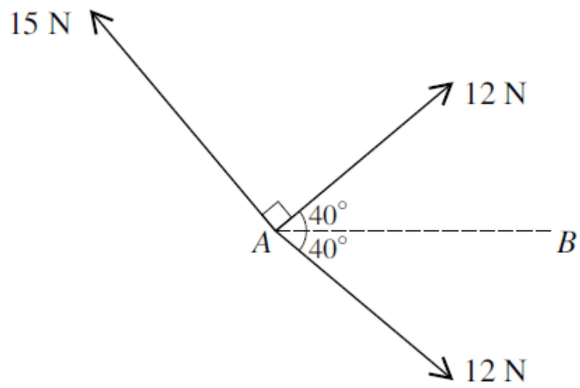


A smooth ring R of mass 0.16 kg is threaded on a light inextensible string. The ends of the string are attached to fixed points A and B. A horizontal force of magnitude 11.2 N acts on R, in the same vertical plane as A and B. The ring is in equilibrium. The string is taut with angle $ARB = 90°$, and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

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

(ii) Hence find T and θ. [3]

(i) $Tcos\theta + Tsin\theta = 11.2, -Tcos\theta + Tsin\theta = 0.16g$
(ii) 8, 53.1°



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]

(i) (a) 8.74
(b) 11.5
(ii) 14.4, 52.7° anticlockwise from ***i*** direction.

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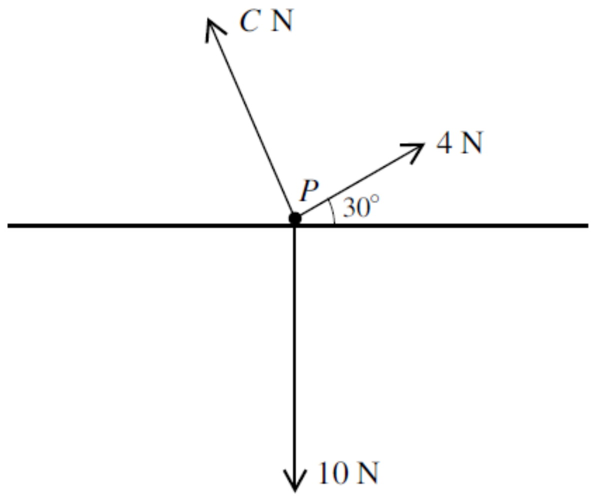

A particle P has weight 10 N and is in limiting equilibrium on a rough horizontal table. The forces shown in the diagram represent the weight of P, an applied force of magnitude 4 N acting on P in a direction at 30° above the horizontal, and the contact force exerted on P by the table (the resultant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

(i) 8.72
(ii) 0.433

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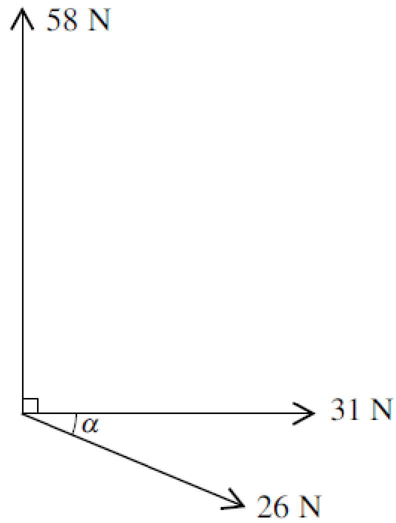

Coplanar forces of magnitudes 58 N, 31 N and 26 N act at a point in the directions shown in the diagram. Given that $\tan \alpha = \frac{5}{12}$, find the magnitude and direction of the resultant of the three forces. [6]

73, 41.1° to ***I*** direction

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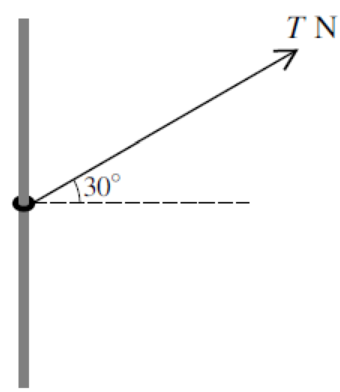
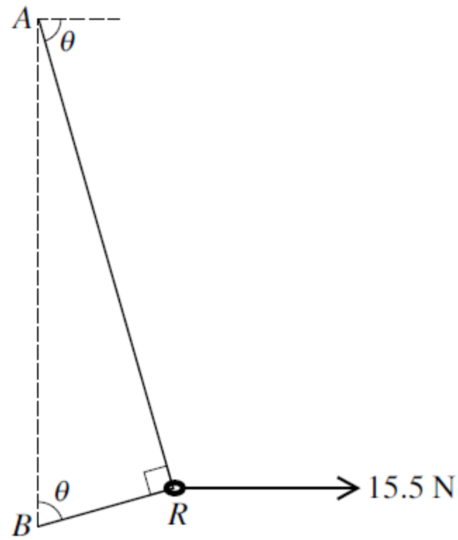


The diagram shows a ring of mass 2 kg threaded on a fixed rough vertical rod. A light string is attached to the ring and is pulled upwards at an angle of 30° to the horizontal. The tension in the string is T N. The coefficient of friction between the ring and the rod is 0.24. Find the two values of T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

28.3, 68.5



A small smooth ring R of weight 8.5 N is threaded on a light inextensible string. The ends of the string are attached to fixed points A and B, with A vertically above B. A horizontal force of magnitude 15.5 N acts on R so that the ring is in equilibrium with angle $ARB = 90°$. The part AR of the string makes an angle θ with the horizontal and the part BR makes an angle θ with the vertical (see diagram). The tension in the string is T N. Show that $T \sin \theta = 12$ and $T \cos \theta = 3.5$ and hence find θ. [6]

73.7^{o}

MAY/JUNE2011 9709/41

A block of mass 11 kg is at rest on a rough plane inclined at 30° to the horizontal. A force acts on the block in a direction up the plane parallel to a line of greatest slope. When the magnitude of the force is $2X$ N the block is on the point of sliding down the plane, and when the magnitude of the force is $9X$ N the block is on the point of sliding up the plane. Find

(i) the value of X, [3]

(ii) the coefficient of friction between the block and the plane. [4]

(i) 10
(ii) 0.367

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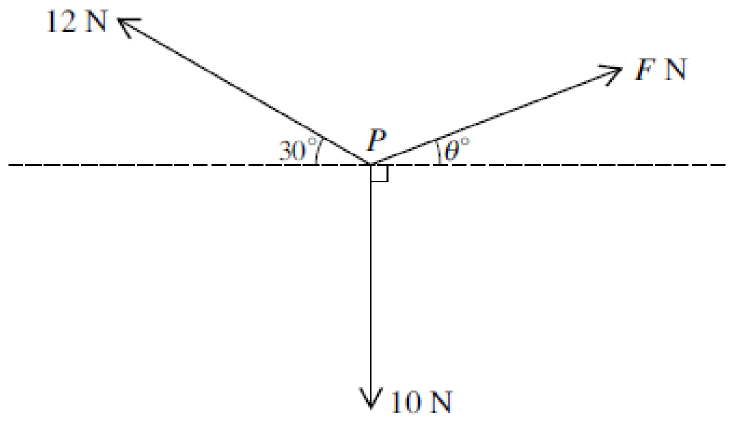
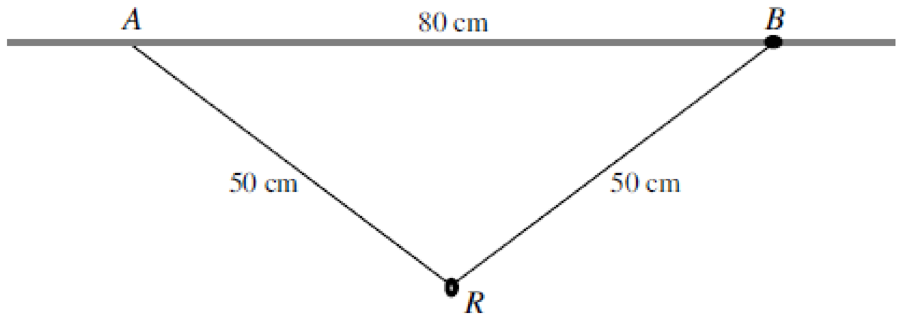


The three coplanar forces shown in the diagram act at a point P and are in equilibrium.

(i) Find the values of F and θ. [6]

(ii) State the magnitude and direction of the resultant force at P when the force of magnitude 12 N is removed. [2]

(i) 11.1, 21.1^{o}
(ii) 12, 30^{o} clockwise from +ve x-axis.



A small smooth ring R, of mass 0.6 kg, is threaded on a light inextensible string of length 100 cm. One end of the string is attached to a fixed point A. A small bead B of mass 0.4 kg is attached to the other end of the string, and is threaded on a fixed rough horizontal rod which passes through A. The system is in equilibrium with B at a distance of 80 cm from A (see diagram).

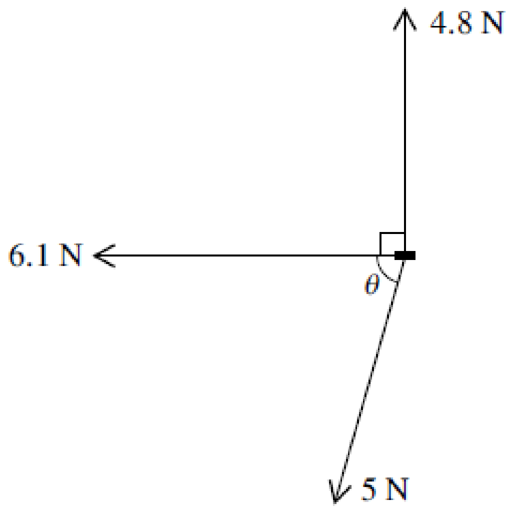
(i) Find the tension in the string. [3]

(ii) Find the frictional and normal components of the contact force acting on B. [4]

(iii) Given that the equilibrium is limiting, find the coefficient of friction between the bead and the rod. [2]

(i) 5
(ii) 4, 7
(iii) 0.571

MAY/JUNE2011 9709/43



A small block of mass 1.25 kg is on a horizontal surface. Three horizontal forces, with magnitudes and directions as shown in the diagram, are applied to the block. The angle θ is such that $\cos\theta = 0.28$ and $\sin\theta = 0.96$. A horizontal frictional force also acts on the block, and the block is in equilibrium.

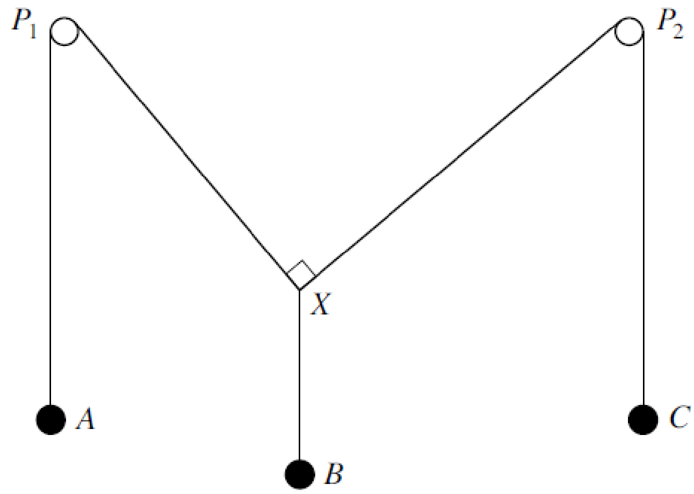
(i) Show that the magnitude of the frictional force is 7.5 N and state the direction of this force. [4]

(ii) Given that the block is in limiting equilibrium, find the coefficient of friction between the block and the surface. [2]

The force of magnitude 6.1 N is now replaced by a force of magnitude 8.6 N acting in the same direction, and the block begins to move.

(iii) Find the magnitude and direction of the acceleration of the block. [3]

(i) 7.5, Frictional force acts parallel to x-axis and to the right.
(ii) 0.6
(iii) 2, Direction of acceleration is parallel to x-axis and to the left.



The diagram shows three particles A, B and C hanging freely in equilibrium, each being attached to the end of a string. The other ends of the three strings are tied together and are at the point X. The strings carrying A and C pass over smooth fixed horizontal pegs P_1 and P_2 respectively. The weights of A, B and C are 5.5 N, 7.3 N and W N respectively, and the angle P_1XP_2 is a right angle. Find the angle AP_1X and the value of W. [5]

4.8

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A block of mass 400 kg rests in limiting equilibrium on horizontal ground. A force of magnitude 2000 N acts on the block at an angle of 15° to the upwards vertical. Find the coefficient of friction between the block and the ground, correct to 2 significant figures. [5]

0.25

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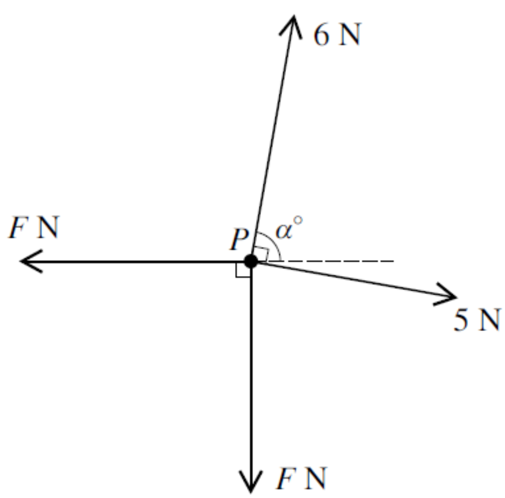
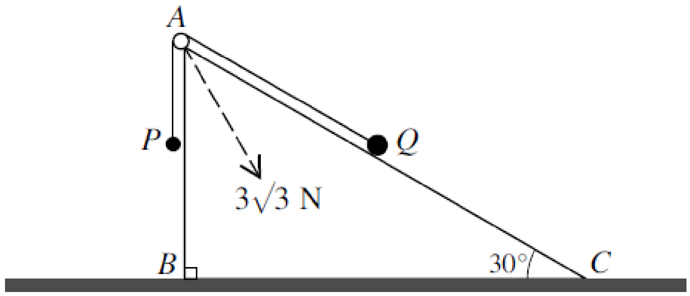


A particle P is in equilibrium on a smooth horizontal table under the action of four horizontal forces of magnitudes 6 N, 5 N, F N and F N acting in the directions shown. Find the values of α and F. [6]

84.8°, 5.52



A small smooth pulley is fixed at the highest point A of a cross-section ABC of a triangular prism. Angle $ABC = 90°$ and angle $BCA = 30°$. The prism is fixed with the face containing BC in contact with a horizontal surface. Particles P and Q are attached to opposite ends of a light inextensible string, which passes over the pulley. The particles are in equilibrium with P hanging vertically below the pulley and Q in contact with AC. The resultant force exerted on the pulley by the string is $3\sqrt{3}$ N (see diagram).

(i) Show that the tension in the string is 3 N. [2]

The coefficient of friction between Q and the prism is 0.75.

(ii) Given that Q is in limiting equilibrium and on the point of moving upwards, find its mass. [5]

(ii) 0.261

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A force of magnitude F N acts in a horizontal plane and has components 27.5 N and −24 N in the x-direction and the y-direction respectively. The force acts at an angle of $\alpha°$ below the x-axis.

(i) Find the values of F and α. [4]

A second force, of magnitude 87.6 N, acts in the same plane at 90° anticlockwise from the force of magnitude F N. The resultant of the two forces has magnitude R N and makes an angle of $\theta°$ with the positive x-axis.

(ii) Find the values of R and θ. [3]

(i) 36.5, 41.1°

(ii) 94.9, 26.3°

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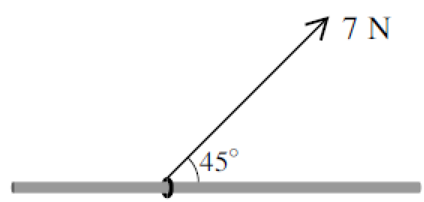
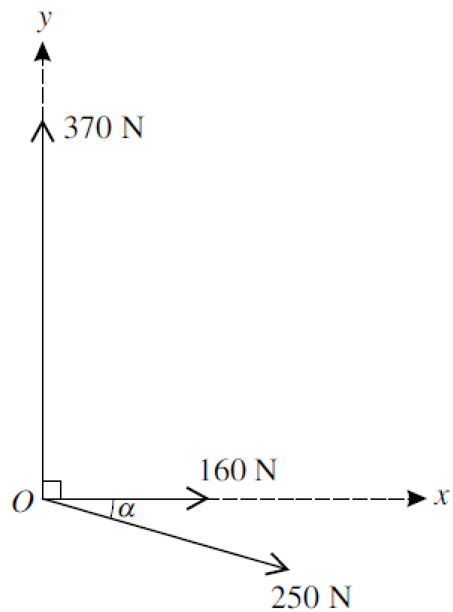


A small ring of mass 0.8 kg is threaded on a rough rod which is fixed horizontally. The ring is in equilibrium, acted on by a force of magnitude 7 N pulling upwards at 45° to the horizontal (see diagram).

(i) Show that the normal component of the contact force acting on the ring has magnitude 3.05 N, correct to 3 significant figures. [2]

(ii) The ring is in limiting equilibrium. Find the coefficient of friction between the ring and the rod. [3]

(ii) 1.62



Coplanar forces of magnitudes 250 N, 160 N and 370 N act at a point O in the directions shown in the diagram, where the angle α is such that $\sin\alpha = 0.28$ and $\cos\alpha = 0.96$. Calculate the magnitude of the resultant of the three forces. Calculate also the angle that the resultant makes with the x-direction. [7]

500, 36.9°

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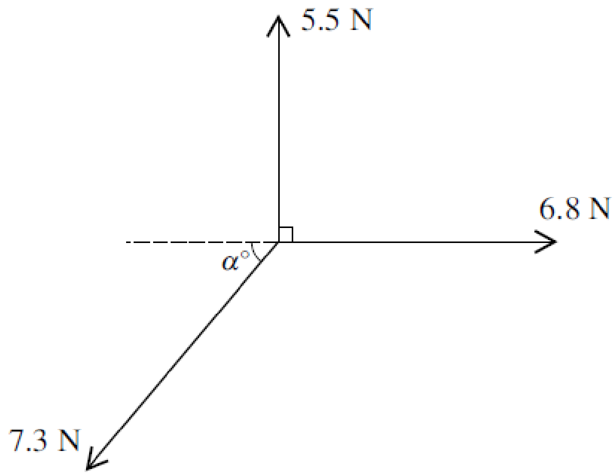

Three coplanar forces act at a point. The magnitudes of the forces are 5.5 N, 6.8 N and 7.3 N, and the directions in which the forces act are as shown in the diagram. Given that the resultant of the three forces is in the same direction as the force of magnitude 6.8 N, find the value of α and the magnitude of the resultant. [4]

48.9°, 2

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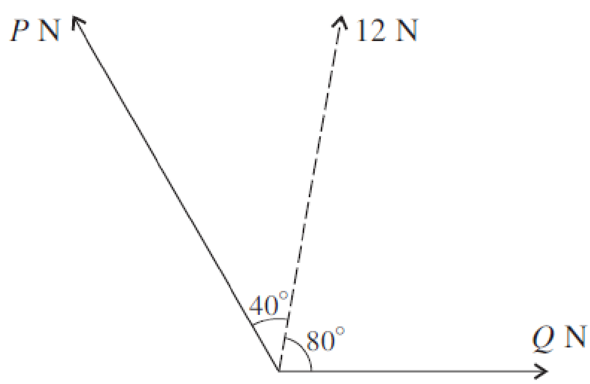

Two forces have magnitudes P N and Q N. The resultant of the two forces has magnitude 12 N and acts in a direction 40° clockwise from the force of magnitude P N and 80° anticlockwise from the force of magnitude Q N (see diagram). Find the value of Q. [4]

8.91

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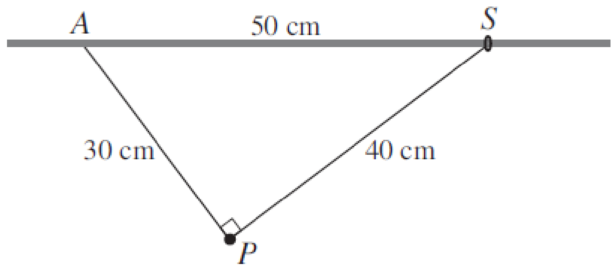

A particle P of weight 5 N is attached to one end of each of two light inextensible strings of lengths 30 cm and 40 cm. The other end of the shorter string is attached to a fixed point A of a rough rod which is fixed horizontally. A small ring S of weight W N is attached to the other end of the longer string and is threaded on to the rod. The system is in equilibrium with the strings taut and $AS = 50$ cm (see diagram).

(i) By resolving the forces acting on P in the direction of PS, or otherwise, find the tension in the longer string. [3]

(ii) Find the magnitude of the frictional force acting on S. [2]

(iii) Given that the coefficient of friction between S and the rod is 0.75, and that S is in limiting equilibrium, find the value of W. [3]

(i) 3
(ii) 2.4
(iii) 1.4

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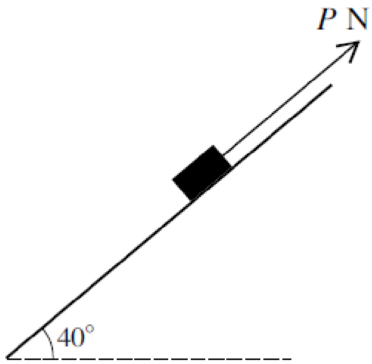


Fig. 1

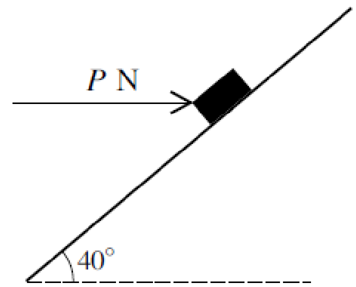


Fig. 2

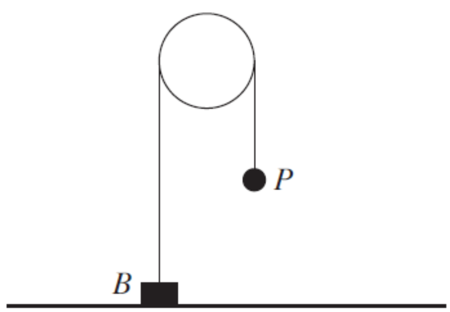
A small block of weight 12 N is at rest on a smooth plane inclined at 40° to the horizontal. The block is held in equilibrium by a force of magnitude P N. Find the value of P when

(i) the force is parallel to the plane as in Fig. 1, [2]

(ii) the force is horizontal as in Fig. 2. [2]

(i) 7.71
(ii) 10.1

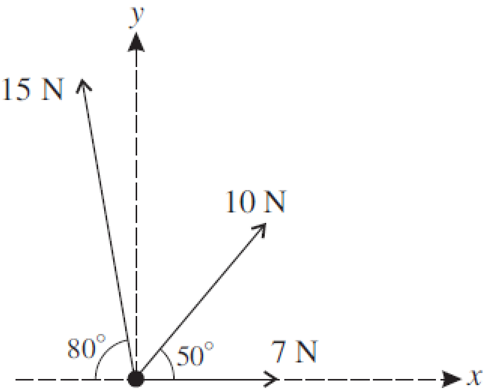
MAY/JUNE2009



A block B of mass 5 kg is attached to one end of a light inextensible string. A particle P of mass 4 kg is attached to other end of the string. The string passes over a smooth pulley. The system is in equilibrium with the string taut and its straight parts vertical. B is at rest on the ground (see diagram). State the tension in the string and find the force exerted on B by the ground. [3]

T = 40, F = 10

MAY/JUNE2009



Forces of magnitudes 7 N, 10 N and 15 N act on a particle in the directions shown in the diagram.

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

(a) in the x-direction,

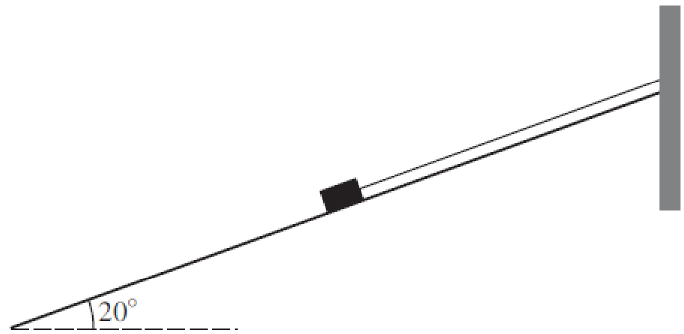
(b) in the y-direction. [3]

(ii) Hence find the direction of the resultant. [2]

(i) (a) 10.8

(b) 22.4

(ii) 64.2^{o} anticlockwise from x-axis



A block of mass 8 kg is at rest on a plane inclined at 20° to the horizontal. The block is connected to a vertical wall at the top of the plane by a string. The string is taut and parallel to a line of greatest slope of the plane (see diagram).

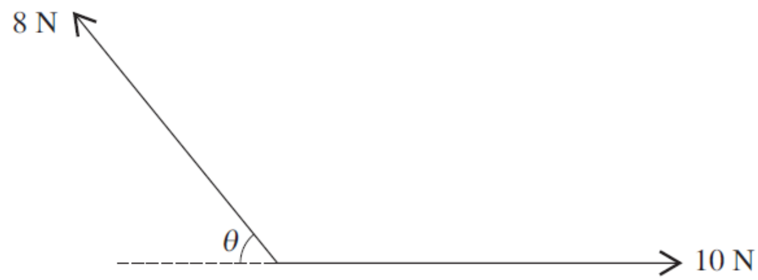
(i) Given that the tension in the string is 13 N, find the frictional and normal components of the force exerted on the block by the plane. [4]

The string is cut; the block remains at rest, but is on the point of slipping down the plane.

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

(i) Frictional component = 14.4, Normal component = 75.2
(ii) 0.364

OCTOBER/NOVEMBER2008



Forces of magnitudes 10 N and 8 N act in directions as shown in the diagram.

(i) Write down in terms of θ the component of the resultant of the two forces

(a) parallel to the force of magnitude 10 N, [1]

(b) perpendicular to the force of magnitude 10 N. [1]

(ii) The resultant of the two forces has magnitude 8 N. Show that $\cos\theta = \frac{5}{8}$. [3]

(i) (a) $10 - 8cos\theta$

(b) $8sin\theta$

OCTOBER/NOVEMBER2008

A block of mass 20 kg is at rest on a plane inclined at 10° to the horizontal. A force acts on the block parallel to a line of greatest slope of the plane. The coefficient of friction between the block and the plane is 0.32. Find the least magnitude of the force necessary to move the block,

(i) given that the force acts up the plane,

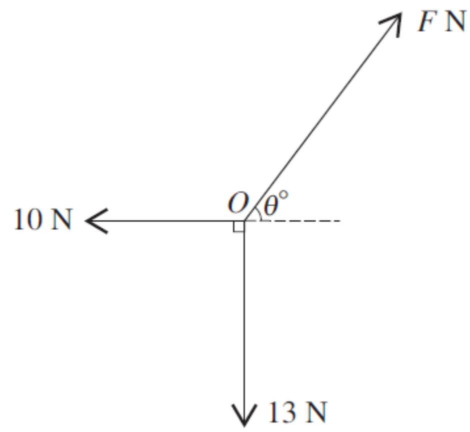
(ii) given instead that the force acts down the plane.

[6]

(i) 97.8

(ii) 28.3

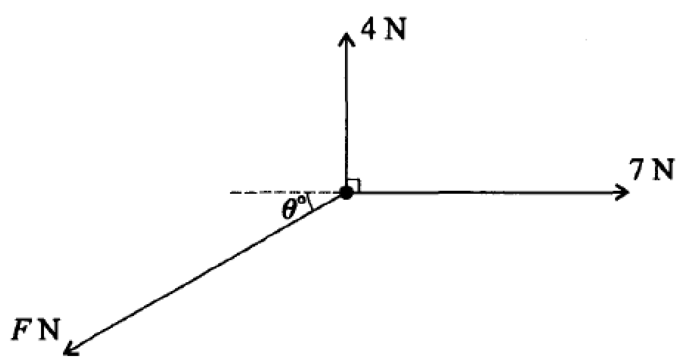
MAY/JUNE2008



Three horizontal forces of magnitudes F N, 13 N and 10 N act at a fixed point O and are in equilibrium. The directions of the forces are as shown in the diagram. Find, in either order, the value of θ and the value of F. [5]

52.4°, 16.4

OCTOBER/NOVEMBER2007



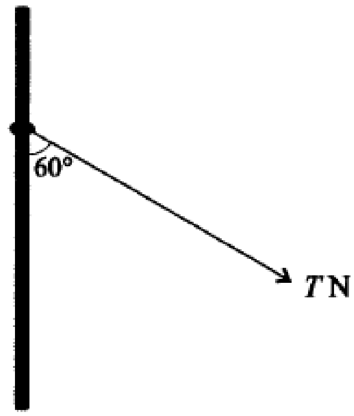
A particle is in equilibrium on a smooth horizontal table when acted on by the three horizontal forces shown in the diagram.

(i) Find the values of F and θ. [4]

(ii) The force of magnitude 7 N is now removed. State the magnitude and direction of the resultant of the remaining two forces. [2]

(i) 8.06, 29.7°
(ii) Magnitude = 7N, Direction opposite to that of the force of magnitude 7N.

OCTOBER/NOVEMBER2007



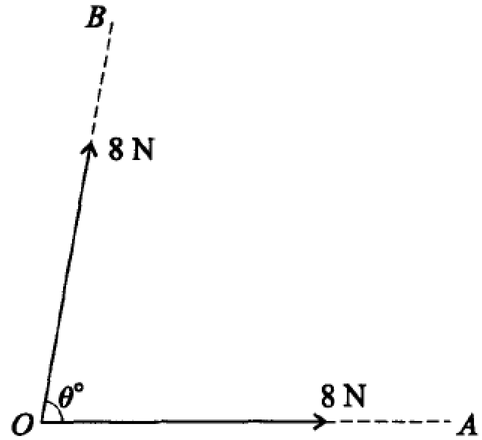
A ring of mass 4 kg is threaded on a fixed rough vertical rod. A light string is attached to the ring, and is pulled with a force of magnitude T N acting at an angle of 60° to the downward vertical (see diagram). The ring is in equilibrium.

(i) The normal and frictional components of the contact force exerted on the ring by the rod are R N and F N respectively. Find R and F in terms of T. [4]

(ii) The coefficient of friction between the rod and the ring is 0.7. Find the value of T for which the ring is about to slip. [3]

(i) $R = T\sin 60°, F = 40 + T\cos 60°$
(ii) 377

MAY/JUNE2007



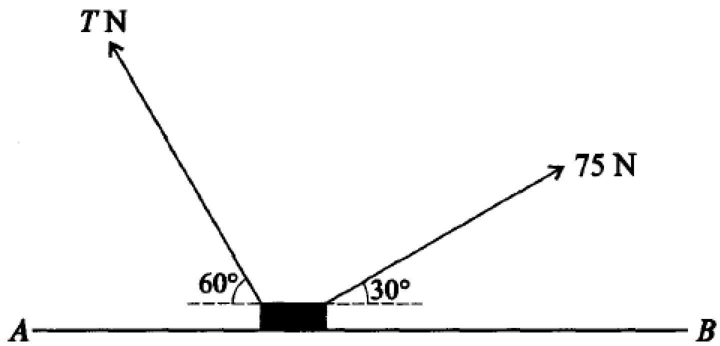
Two forces, each of magnitude 8 N, act at a point in the directions OA and OB. The angle between the forces is $\theta°$ (see diagram). The resultant of the two forces has component 9 N in the direction OA. Find

(i) the value of θ, [2]

(ii) the magnitude of the resultant of the two forces. [3]

(i) 82.8°
(ii) 12

MAY/JUNE2007



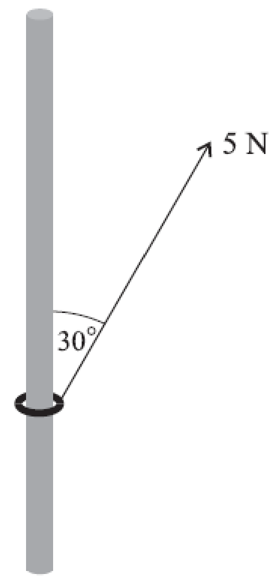
Two light strings are attached to a block of mass 20 kg. The block is in equilibrium on a horizontal surface AB with the strings taut. The strings make angles of 60° and 30° with the horizontal, on either side of the block, and the tensions in the strings are T N and 75 N respectively (see diagram).

(i) Given that the surface is smooth, find the value of T and the magnitude of the contact force acting on the block. **[5]**

(ii) It is given instead that the surface is rough and that the block is on the point of slipping. The frictional force on the block has magnitude 25 N and acts towards A. Find the coefficient of friction between the block and the surface. **[6]**

(i) T = 130, Magnitude = 50
(ii) 0.268

OCTOBER/NOVEMBER2006



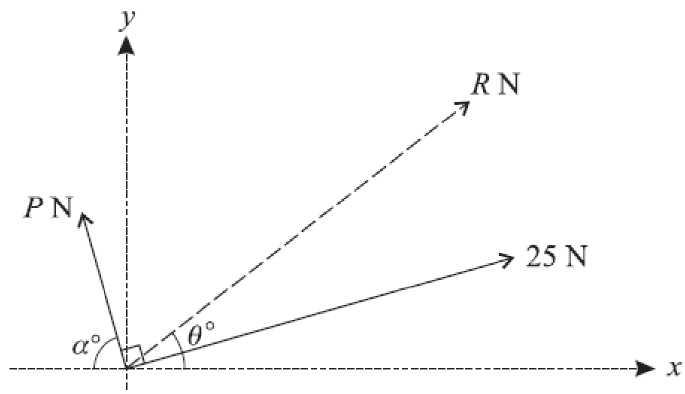
A small ring of mass 0.6 kg is threaded on a rough rod which is fixed vertically. The ring is in equilibrium, acted on by a force of magnitude 5 N pulling upwards at 30° to the vertical (see diagram).

(i) Show that the frictional force acting on the ring has magnitude 1.67 N, correct to 3 significant figures. [2]

(ii) The ring is on the point of sliding down the rod. Find the coefficient of friction between the ring and the rod. [3]

(ii) 0.668

OCTOBER/NOVEMBER2006



Forces of magnitudes P N and 25 N act at right angles to each other. The resultant of the two forces has magnitude R N and makes an angle of $\theta°$ with the x-axis (see diagram). The force of magnitude P N has components -2.8 N and 9.6 N in the x-direction and the y-direction respectively, and makes an angle of $\alpha°$ with the negative x-axis.

(i) Find the values of P and R. [3]

(ii) Find the value of α, and hence find the components of the force of magnitude 25 N in

(a) the x-direction,

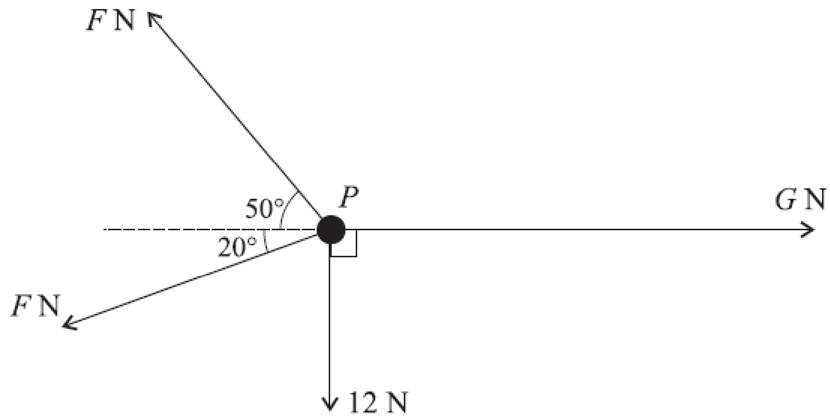
(b) the y-direction.

[4]

(iii) Find the value of θ. [3]

(i) 10, 26.9
(ii) (a) 24
(b) 7
(iii) 38.1°

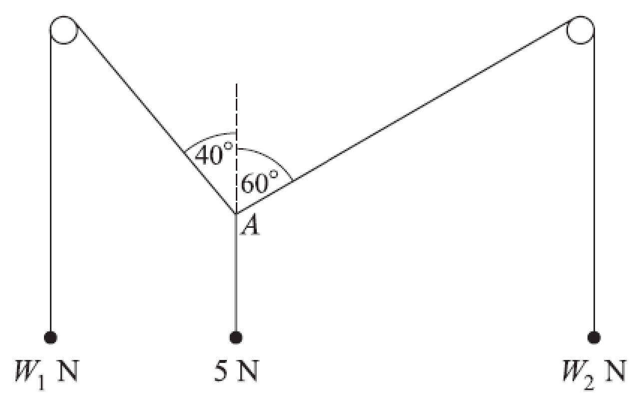
MAY/JUNE2006



A particle P is in equilibrium on a smooth horizontal table under the action of horizontal forces of magnitudes F N, F N, G N and 12 N acting in the directions shown. Find the values of F and G. [6]

F = 28.3, G = 44.8

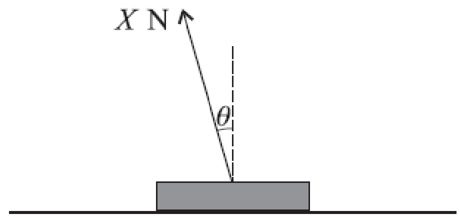
OCTOBER/NOVEMBER2005



Each of three light strings has a particle attached to one of its ends. The other ends of the strings are tied together at a point A. The strings are in equilibrium with two of them passing over fixed smooth horizontal pegs, and with the particles hanging freely. The weights of the particles, and the angles between the sloping parts of the strings and the vertical, are as shown in the diagram. Find the values of W_1 and W_2. [6]

4.40, 3.26

OCTOBER/NOVEMBER2005



A stone slab of mass 320 kg rests in equilibrium on rough horizontal ground. A force of magnitude X N acts upwards on the slab at an angle of θ to the vertical, where $\tan\theta = \frac{7}{24}$ (see diagram).

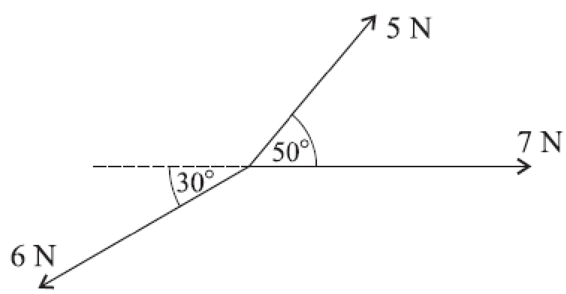
(i) Find, in terms of X, the normal component of the force exerted on the slab by the ground. [3]

(ii) Given that the coefficient of friction between the slab and the ground is $\frac{3}{8}$, find the value of X for which the slab is about to slip. [3]

(i) $N = 3200 - \left(\frac{24}{25}\right)X$

(ii) 1875

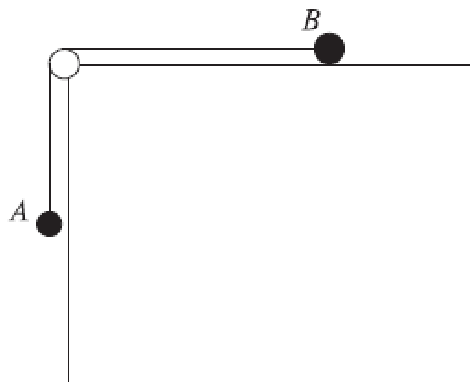
MAY/JUNE2005



Three coplanar forces act at a point. The magnitudes of the forces are 5 N, 6 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 three forces. [6]

5.09, 9.4° anticlockwise from force of magnitude 7N.

MAY/JUNE2005



Particles A and B, of masses 0.2 kg and 0.3 kg respectively, are connected by a light inextensible string. The string passes over a smooth pulley at the edge of a rough horizontal table. Particle A hangs freely and particle B is in contact with the table (see diagram).

(i) The system is in limiting equilibrium with the string taut and A about to move downwards. Find the coefficient of friction between B and the table. [4]

A force now acts on particle B. This force has a vertical component of 1.8 N upwards and a horizontal component of X N directed away from the pulley.

(ii) The system is now in limiting equilibrium with the string taut and A about to move **upwards**. Find X. [3]

(i) $\frac{2}{3}$
(ii) 2.8

OCTOBER/NOVEMBER2004

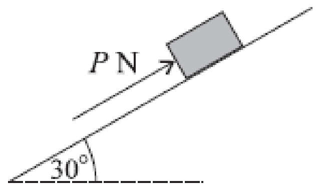


Fig. 1

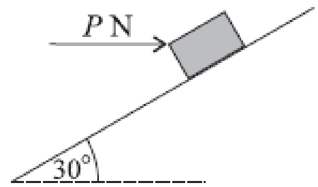


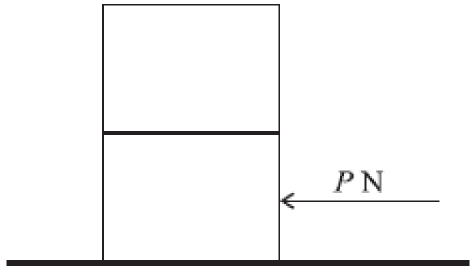
Fig. 2

A small block of weight 18 N is held at rest on a smooth plane inclined at 30° to the horizontal, by a force of magnitude P N. Find

(i) the value of P when the force is parallel to the plane, as in Fig. 1, [2]

(ii) the value of P when the force is horizontal, as in Fig. 2. [3]

(i) 9
(ii) 10.4



Two identical boxes, each of mass 400 kg, are at rest, with one on top of the other, on horizontal ground. A horizontal force of magnitude P newtons is applied to the lower box (see diagram). The coefficient of friction between the lower box and the ground is 0.75 and the coefficient of friction between the two boxes is 0.4.

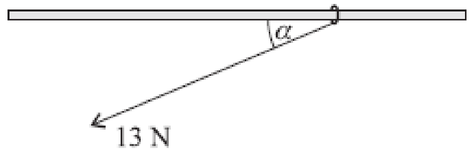
(i) Show that the boxes will remain at rest if $P \leqslant 6000$. [2]

The boxes start to move with acceleration $a\,\mathrm{m\,s^{-2}}$.

(ii) Given that no sliding takes place between the boxes, show that $a \leqslant 4$ and deduce the maximum possible value of P. [7]

Maximum P = 9200

MAY/JUNE2004



A ring of mass 1.1 kg is threaded on a fixed rough horizontal rod. A light string is attached to the ring and the string is pulled with a force of magnitude 13 N at an angle α below the horizontal, where $\tan\alpha = \frac{5}{12}$ (see diagram). The ring is in equilibrium.

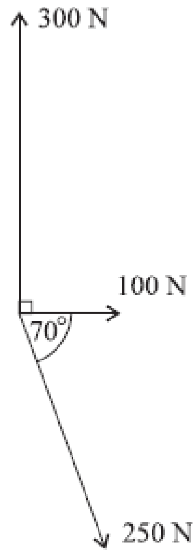
(i) Find the frictional component of the contact force on the ring. [2]

(ii) Find the normal component of the contact force on the ring. [2]

(iii) Given that the equilibrium of the ring is limiting, find the coefficient of friction between the ring and the rod. [1]

(i) 12
(ii) 16
(iii) 0.75

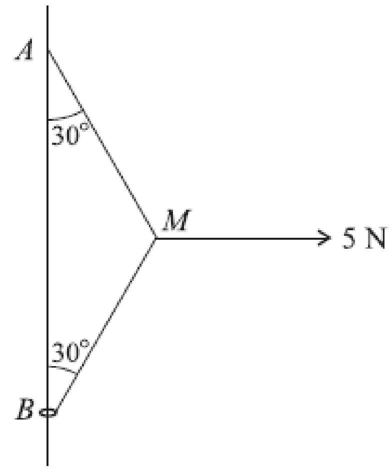
MAY/JUNE2004



Coplanar forces of magnitudes 250 N, 100 N and 300 N act at a point in the directions shown in the diagram. The resultant of the three forces has magnitude R N, and acts at an angle α° anticlockwise from the force of magnitude 100 N. Find R and α. [6]

197, 19.3°

OCTOBER/NOVEMBER2003



One end of a light inextensible string is attached to a fixed point A of a fixed vertical wire. The other end of the string is attached to a small ring B, of mass 0.2 kg, through which the wire passes. A horizontal force of magnitude 5 N is applied to the mid-point M of the string. The system is in equilibrium with the string taut, with B below A, and with angles ABM and BAM equal to 30° (see diagram).

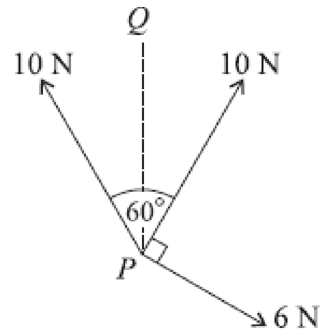
(i) Show that the tension in BM is 5 N. [3]

(ii) The ring is on the point of sliding up the wire. Find the coefficient of friction between the ring and the wire. [5]

(iii) A particle of mass m kg is attached to the ring. The ring is now on the point of sliding down the wire. Given that the coefficient of friction between the ring and the wire is unchanged, find the value of m. [2]

(ii) 0.932
(iii) 0.466

MAY/JUNE2003



Three coplanar forces of magnitudes 10 N, 10 N and 6 N act at a point P in the directions shown in the diagram. PQ is the bisector of the angle between the two forces of magnitude 10 N.

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

(a) in the direction of PQ, [2]

(b) in the direction perpendicular to PQ. [1]

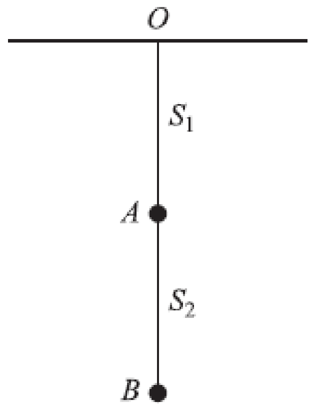
(ii) Find the magnitude of the resultant of the three forces. [2]

(i) (a) 14.3

(b) 5.20

(ii) 15.2

MAY/JUNE2003



S_1 and S_2 are light inextensible strings, and A and B are particles each of mass 0.2 kg. Particle A is suspended from a fixed point O by the string S_1, and particle B is suspended from A by the string S_2. The particles hang in equilibrium as shown in the diagram.

(i) Find the tensions in S_1 and S_2. [3]

The string S_1 is cut and the particles fall. The air resistance acting on A is 0.4 N and the air resistance acting on B is 0.2 N.

(ii) Find the acceleration of the particles and the tension in S_2. [5]

(i) T1 = 0.4, T2 = 0.2
(ii) 8.5

MAY/JUNE2003

A small block of mass 0.15 kg moves on a horizontal surface. The coefficient of friction between the block and the surface is 0.025.

(i) Find the frictional force acting on the block. [2]

(ii) Show that the deceleration of the block is $0.25\ \mathrm{m\,s^{-2}}$. [2]

The block is struck from a point *A* on the surface and, 4 s later, it hits a boundary board at a point *B*. The initial speed of the block is $5.5\ \mathrm{m\,s^{-1}}$.

(iii) Find the distance *AB*. [2]

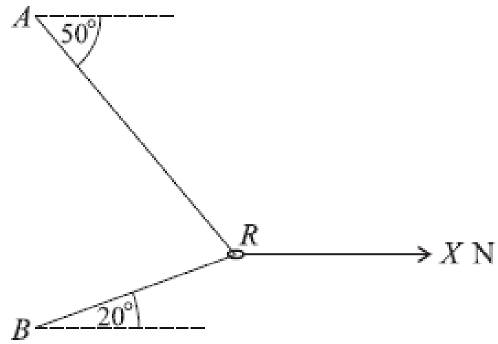
The block rebounds from the board with a speed of $3.5\ \mathrm{m\,s^{-1}}$ and moves along the line *BA*. Find

(iv) the speed with which the block passes through *A*, [2]

(v) the total distance moved by the block, from the instant when it was struck at *A* until the instant when it comes to rest. [2]

(i) 0.0375
(ii) 0.25
(iii) 20
(iv) 1.5
(v) 44.5

OCTOBER/NOVEMBER2002



A light inextensible string has its ends attached to two fixed points A and B, with A vertically above B. A smooth ring R, of mass 0.8 kg, is threaded on the string and is pulled by a horizontal force of magnitude X newtons. The sections AR and BR of the string make angles of 50° and 20° respectively with the horizontal, as shown in the diagram. The ring rests in equilibrium with the string taut. Find

(i) the tension in the string, [3]

(ii) the value of X. [3]

(i) 18.9
(ii) 29.9

OCTOBER/NOVEMBER2002

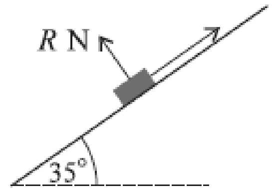
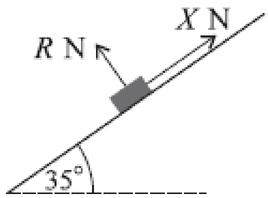


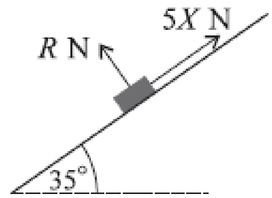
Fig. 1

A force, whose direction is upwards parallel to a line of greatest slope of a plane inclined at 35° to the horizontal, acts on a box of mass 15 kg which is at rest on the plane. The normal component of the contact force on the box has magnitude R newtons (see Fig. 1).

(i) Show that $R = 123$, correct to 3 significant figures. [1]



about to move down



about to move up

Fig. 2

When the force parallel to the plane acting on the box has magnitude X newtons the box is about to move *down* the plane, and when this force has magnitude $5X$ newtons the box is about to move *up* the plane (see Fig. 2).

(ii) Find the value of X and the coefficient of friction between the box and the plane. [7]

(ii) X = 28.7, 0.467

MAY/JUNE2002

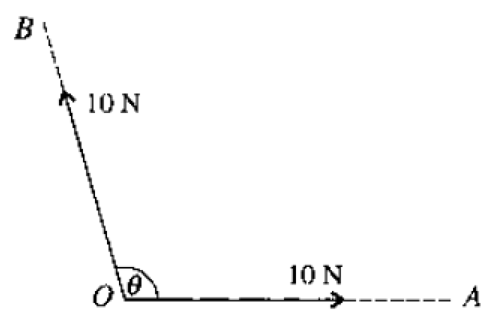
A basket of mass 5 kg slides down a slope inclined at $12°$ to the horizontal. The coefficient of friction between the basket and the slope is 0.2.

(i) Find the frictional force acting on the basket. [2]

(ii) Determine whether the speed of the basket is increasing or decreasing. [3]

(i) 9.78
(ii) increasing

MAY/JUNE2002



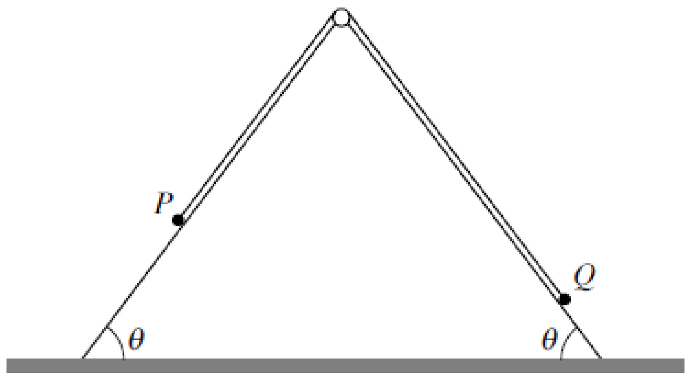
Two forces, each of magnitude 10 N, act at a point O in the directions of OA and OB, as shown in the diagram. The angle between the forces is θ. The resultant of these two forces has magnitude 12 N.

(i) Find θ. [3]

(ii) Find the component of the resultant force in the direction of OA. [2]

(i) 106.3^{o}
(ii) 7.2

NEWTON'S LAW



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 $2\,\text{m}\,\text{s}^{-1}$. 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]

(i) T = 3.84, a = 1.6
(ii) 1.5

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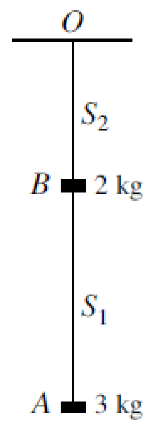

A block A of mass 3 kg is attached to one end of a light inextensible string S_1. Another block B of mass 2 kg is attached to the other end of S_1, and is also attached to one end of another light inextensible string S_2. The other end of S_2 is attached to a fixed point O and the blocks hang in equilibrium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

(i) T(S1) = 30, T(S2) = 50
(ii) T = 1.76, a = 8.88

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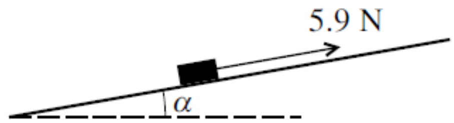

Fig. 1

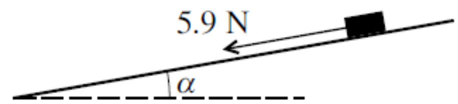

Fig. 2

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 $\mu \geqslant \frac{4}{5}$. [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 $1.7\ \mathrm{m\,s^{-2}}$ when the force acts down the plane, find the value of μ. [2]

(ii) 0.994

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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]

T = 4.55, R = 9.1

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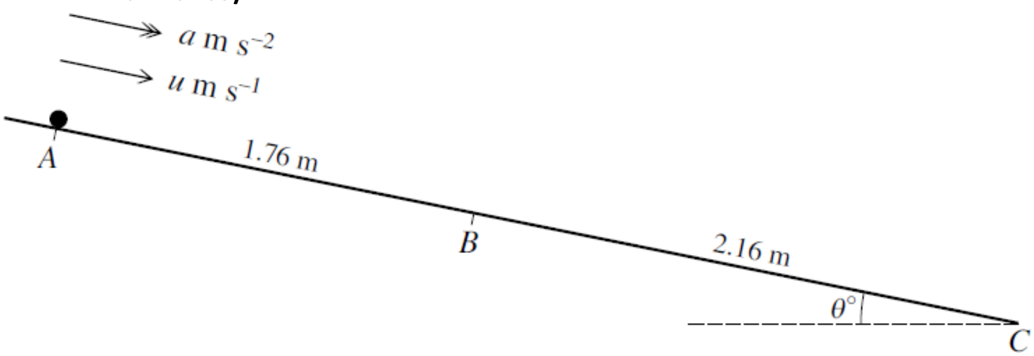

A, B and C are three points on a line of greatest slope of a smooth plane inclined at an angle of $\theta°$ to the horizontal. A is higher than B and B is higher than C, and the distances AB and BC are 1.76 m and 2.16 m respectively. A particle slides down the plane with constant acceleration a m s^{-2}. The speed of the particle at A is u 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]

(i) $\mu = 1.4, a = 2$
(ii) 11.5

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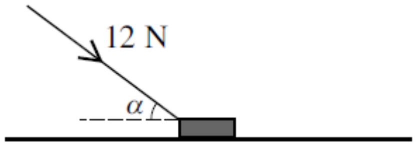

Fig. 1

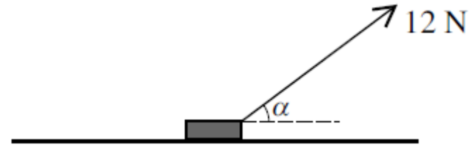

Fig. 2

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 $\mu \geqslant \frac{6}{17}$. [5]

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

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

(ii) $\mu < \frac{3}{4}$

OCTOBER/NOVEMBER2011 9709/42

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 $3\,\mathrm{m\,s^{-1}}$, find how far the block travels. [2]

(i) 0.589
(ii) 7.64

OCTOBER/NOVEMBER2011 9709/42

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]

(i) a = 2, T = 7.2
(ii) 2.25

OCTOBER/NOVEMBER2011 9709/43

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]

0.8

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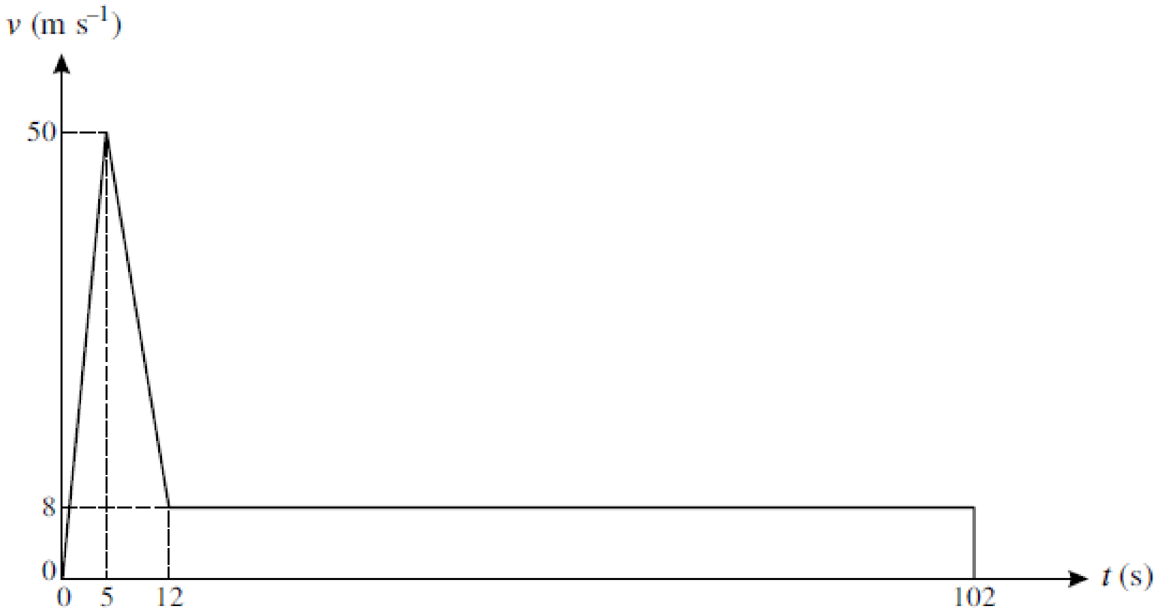

The velocity-time graph shown models the motion of a parachutist falling vertically. There are four stages in the motion:

- falling freely with the parachute closed,
- decelerating at a constant rate with the parachute open,
- falling with constant speed with the parachute open,
- coming to rest instantaneously on hitting the ground.

(i) Show that the total distance fallen is 1048 m. [2]

The weight of the parachutist is 850 N.

(ii) Find the upward force on the parachutist due to the parachute, during the second stage. [5]

(ii) 1360

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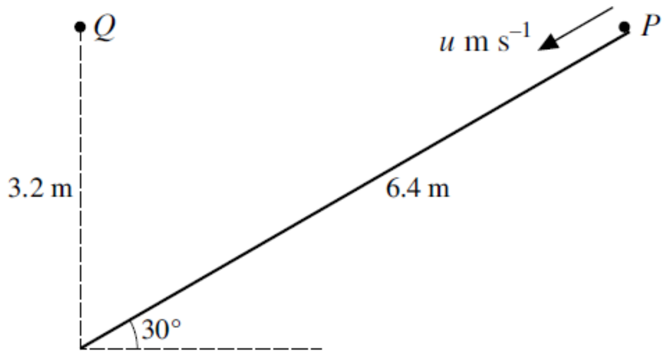
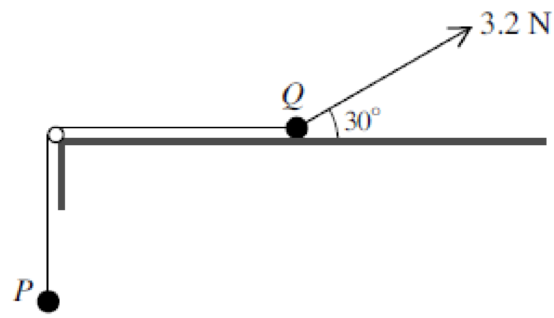


A particle P is projected from the top of a smooth ramp with speed u m s^{-1}, and travels down a line of greatest slope. The ramp has length 6.4 m and is inclined at 30° to the horizontal. Another particle Q is released from rest at a point 3.2 m vertically above the bottom of the ramp, at the same instant that P is projected (see diagram). Given that P and Q reach the bottom of the ramp simultaneously, find

(i) the value of u, [4]

(ii) the speed with which P reaches the bottom of the ramp. [2]

(i) 6
(ii) 10



Particles P and Q, of masses 0.2 kg and 0.5 kg respectively, are connected by a light inextensible string. The string passes over a smooth pulley at the edge of a rough horizontal table. P hangs freely and Q is in contact with the table. A force of magnitude 3.2 N acts on Q, upwards and away from the pulley, at an angle of 30° to the horizontal (see diagram).

(i) The system is in limiting equilibrium with P about to move upwards. Find the coefficient of friction between Q and the table. [6]

The force of magnitude 3.2 N is now removed and P starts to move downwards.

(ii) Find the acceleration of the particles and the tension in the string. [4]

(i) 0.227
(ii) a = 1.24, T = 1.75

OCTOBER/NOVEMBER2010 9709/42

A cyclist, working at a constant rate of 400 W, travels along a straight road which is inclined at 2° to the horizontal. The total mass of the cyclist and his cycle is 80 kg. Ignoring any resistance to motion, find, correct to 1 decimal place, the acceleration of the cyclist when he is travelling

(i) uphill at $4\,\mathrm{m\,s^{-1}}$,

(ii) downhill at $4\,\mathrm{m\,s^{-1}}$.

[5]

(i) 0.9
(ii) 1.6

OCTOBER/NOVEMBER2010 9709/43

A particle P is released from rest at a point on a smooth plane inclined at 30° to the horizontal. Find the speed of P

(i) when it has travelled 0.9 m,

(ii) 0.8 s after it is released.

[4]

(i) 3
(ii) 4

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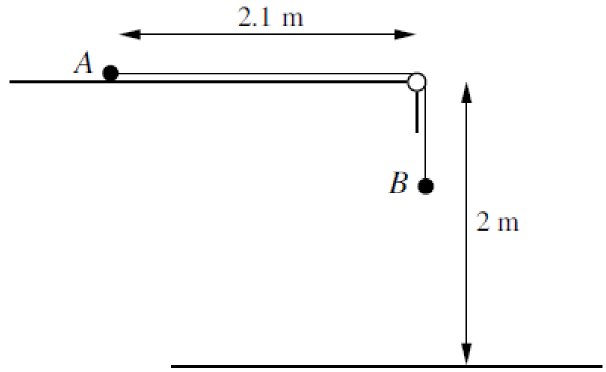
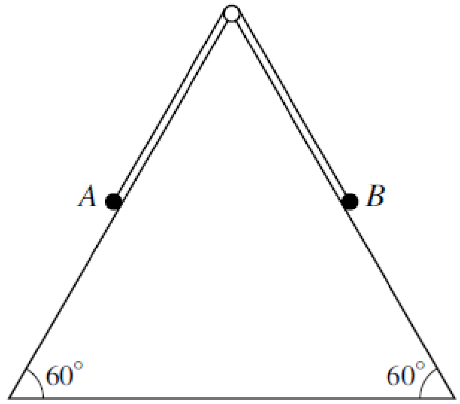


Particles A and B, of masses 0.2 kg and 0.45 kg respectively, are connected by a light inextensible string of length 2.8 m. The string passes over a small smooth pulley at the edge of a rough horizontal surface, which is 2 m above the floor. Particle A is held in contact with the surface at a distance of 2.1 m from the pulley and particle B hangs freely (see diagram). The coefficient of friction between A and the surface is 0.3. Particle A is released and the system begins to move.

(i) Find the acceleration of the particles and show that the speed of B immediately before it hits the floor is 3.95 m s^{-1}, correct to 3 significant figures. [7]

(ii) Given that B remains on the floor, find the speed with which A reaches the pulley. [4]

(i) a = 6
(ii) 3.29



The diagram shows a vertical cross-section of a triangular prism which is fixed so that two of its faces are inclined at 60° to the horizontal. One of these faces is smooth and one is rough. Particles A and B, of masses 0.36 kg and 0.24 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the highest point of the cross-section. B is held at rest at a point of the cross-section on the rough face and A hangs freely in contact with the smooth face (see diagram). B is released and starts to move up the face with acceleration $0.25\ \mathrm{m\,s^{-2}}$.

(i) By considering the motion of A, show that the tension in the string is 3.03 N, correct to 3 significant figures. [2]

(ii) Find the coefficient of friction between B and the rough face, correct to 2 significant figures. [6]

(ii) 0.74

MAY/JUNE2010 9709/43

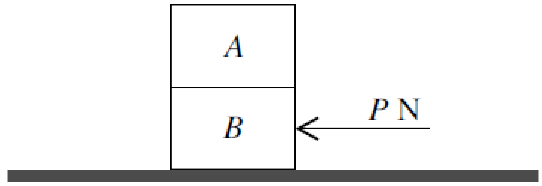
Particles P and Q move on a line of greatest slope of a smooth inclined plane. P is released from rest at a point O on the line and 2 s later passes through the point A with speed $3.5\ \mathrm{m\,s^{-1}}$.

(i) Find the acceleration of P and the angle of inclination of the plane. [4]

At the instant that P passes through A the particle Q is released from rest at O. At time t s after Q is released from O, the particles P and Q are 4.9 m apart.

(ii) Find the value of t. [5]

(i) 1.75, 10.1°
(ii) 0.4



Two rectangular boxes A and B are of identical size. The boxes are at rest on a rough horizontal floor with A on top of B. Box A has mass 200 kg and box B has mass 250 kg. A horizontal force of magnitude P N is applied to B (see diagram). The boxes remain at rest if $P \leqslant 3150$ and start to move if $P > 3150$.

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

The coefficient of friction between the two boxes is 0.2. Given that $P > 3150$ and that no sliding takes place between the boxes,

(ii) show that the acceleration of the boxes is not greater than $2\,\mathrm{m\,s^{-2}}$, [3]

(iii) find the maximum possible value of P. [3]

(i) 0.7
(iii) 4050

OCTOBER/NOVEMBER2009 9709/41

A particle P of mass 0.6 kg moves upwards along a line of greatest slope of a plane inclined at 18° to the horizontal. The deceleration of P is $4\ \mathrm{m\,s^{-2}}$.

(i) Find the frictional and normal components of the force exerted on P by the plane. Hence find the coefficient of friction between P and the plane, correct to 2 significant figures. [6]

After P comes to instantaneous rest it starts to move down the plane with acceleration $a\ \mathrm{m\,s^{-2}}$.

(ii) Find the value of a. [2]

(i) Frictional component = 0.546, Normal component = 5.71, 0.096
(ii) 2.18

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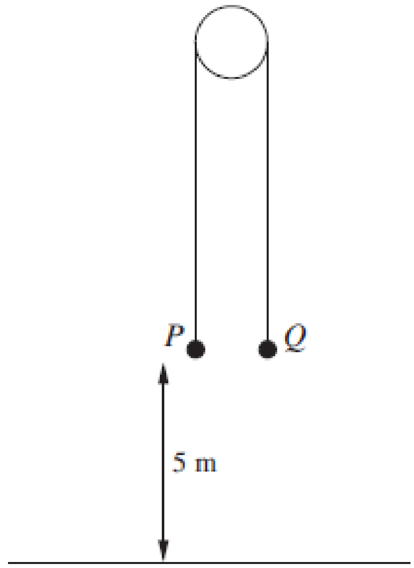


Particles P and Q, of masses 0.55 kg and 0.45 kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. The particles are held at rest with the string taut and its straight parts vertical. Both particles are at a height of 5 m above the ground (see diagram). The system is released.

(i) Find the acceleration with which P starts to move. [3]

The string breaks after 2 s and in the subsequent motion P and Q move vertically under gravity.

(ii) At the instant that the string breaks, find

(a) the height above the ground of P and of Q, [2]

(b) the speed of the particles. [1]

(iii) Show that Q reaches the ground 0.8 s later than P. [4]

(i) 1
(ii) (a) 3, 7
(b) 2

OCTOBER/NOVEMBER2009 9709/42

A particle moves up a line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\cos\alpha = 0.96$ and $\sin\alpha = 0.28$.

(i) Given that the normal component of the contact force acting on the particle has magnitude 1.2 N, find the mass of the particle. [2]

(ii) Given also that the frictional component of the contact force acting on the particle has magnitude 0.4 N, find the deceleration of the particle. [3]

The particle comes to rest on reaching the point X.

(iii) Determine whether the particle remains at X or whether it starts to move down the plane. [2]

(i) 0.125
(ii) -6
(iii) particle remains at rest.

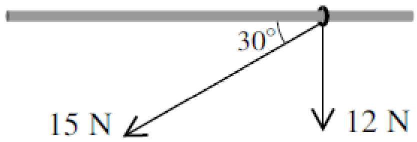


Fig. 1

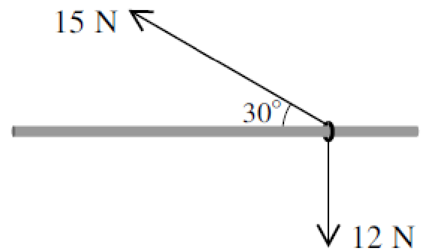


Fig. 2

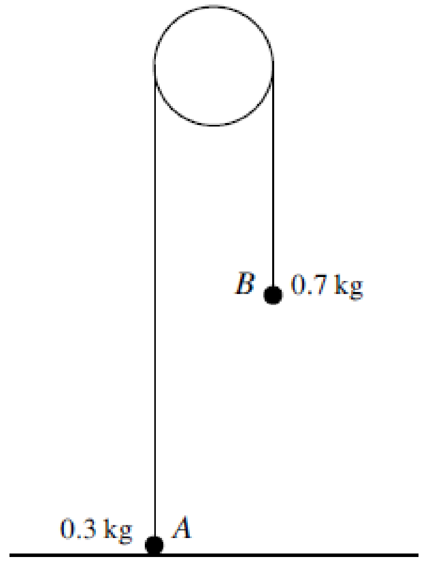
A small ring of weight 12 N is threaded on a fixed rough horizontal rod. A light string is attached to the ring and the string is pulled with a force of 15 N at an angle of 30° to the horizontal.

(i) When the angle of 30° is **below** the horizontal (see Fig. 1), the ring is in limiting equilibrium. Show that the coefficient of friction between the ring and the rod is 0.666, correct to 3 significant figures. [5]

(ii) When the angle of 30° is **above** the horizontal (see Fig. 2), the ring is moving with acceleration $a\,\mathrm{m\,s^{-2}}$. Find the value of a. [4]

(ii) 8.33

OCTOBER/NOVEMBER2009 9709/42



Particles A and B, of masses 0.3 kg and 0.7 kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. Particle A is held on the horizontal floor and particle B hangs in equilibrium. Particle A is released and both particles start to move vertically.

(i) Find the acceleration of the particles. [3]

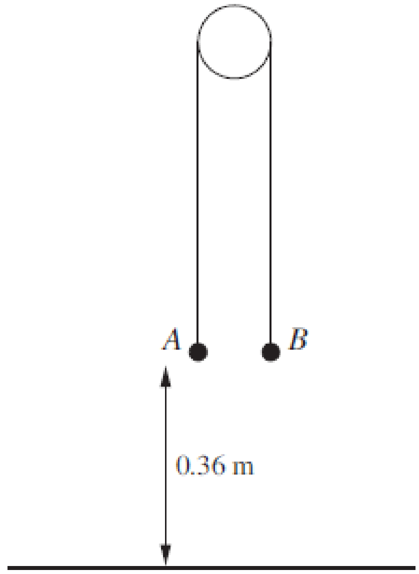
The speed of the particles immediately before B hits the floor is $1.6\,\mathrm{m\,s^{-1}}$. Given that B does not rebound upwards, find

(ii) the maximum height above the floor reached by A, [3]

(iii) the time taken by A, from leaving the floor, to reach this maximum height. [3]

(i) 4
(ii) 0.448
(iii) 0.56

MAY/JUNE2009



Particles A and B are attached to the ends of a light inextensible string which passes over a smooth pulley. The system is held at rest with the string taut and its straight parts vertical. Both particles are at a height of 0.36 m above the floor (see diagram). The system is released and A begins to fall, reaching the floor after 0.6 s.

(i) Find the acceleration of A as it falls. [2]

The mass of A is 0.45 kg. Find

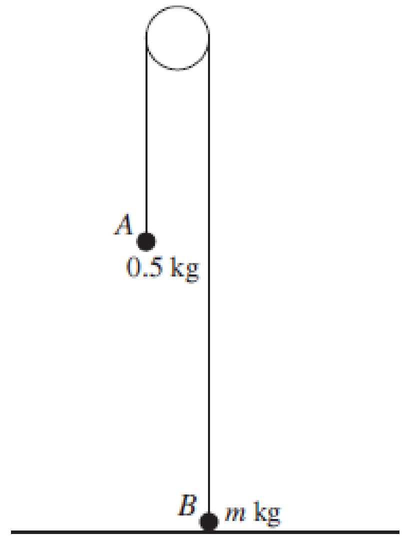
(ii) the tension in the string while A is falling, [2]

(iii) the mass of B, [3]

(iv) the maximum height above the floor reached by B. [3]

(i) 2
(ii) 3.6
(iii) 0.3
(iv) 0.792

OCTOBER/NOVEMBER2008



Particles A and B, of masses 0.5 kg and m kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. Particle B is held at rest on the horizontal floor and particle A hangs in equilibrium (see diagram). B is released and each particle starts to move vertically. A hits the floor 2 s after B is released. The speed of each particle when A hits the floor is $5\,\mathrm{m\,s^{-1}}$.

(i) For the motion while A is moving downwards, find

(a) the acceleration of A, [2]

(b) the tension in the string. [3]

(ii) Find the value of m. [3]

(i) (a) 2.5
(b) 3.75
(ii) 0.3

MAY/JUNE2008

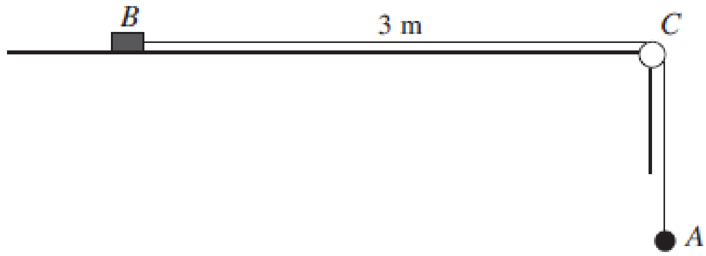
A particle slides down a smooth plane inclined at an angle of $\alpha°$ to the horizontal. The particle passes through the point A with speed $1.5\,\mathrm{m\,s^{-1}}$, and $1.2\,\mathrm{s}$ later it passes through the point B with speed $4.5\,\mathrm{m\,s^{-1}}$. Find

(i) the acceleration of the particle, [2]

(ii) the value of α. [2]

(i) 2.5
(ii) 14.5°

MAY/JUNE2008



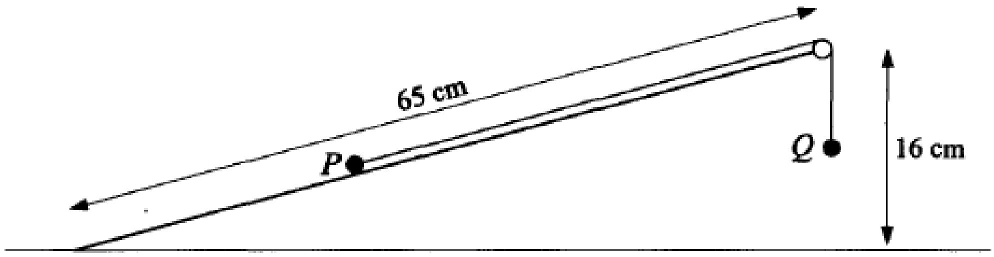
A block B of mass 0.6 kg and a particle A of mass 0.4 kg are attached to opposite ends of a light inextensible string. The block is held at rest on a rough horizontal table, and the coefficient of friction between the block and the table is 0.5. The string passes over a small smooth pulley C at the edge of the table and A hangs in equilibrium vertically below C. The part of the string between B and C is horizontal and the distance BC is 3 m (see diagram). B is released and the system starts to move.

(i) Find the acceleration of B and the tension in the string. [6]

(ii) Find the time taken for B to reach the pulley. [2]

(i) a = 1, T = 3.6
(ii) 2.45

OCTOBER/NOVEMBER2007



A rough inclined plane of length 65 cm is fixed with one end at a height of 16 cm above the other end. Particles P and Q, of masses 0.13 kg and 0.11 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley at the top of the plane. Particle P is held at rest on the plane and particle Q hangs vertically below the pulley (see diagram). The system is released from rest and P starts to move up the plane.

(i) Draw a diagram showing the forces acting on P during its motion up the plane. [1]

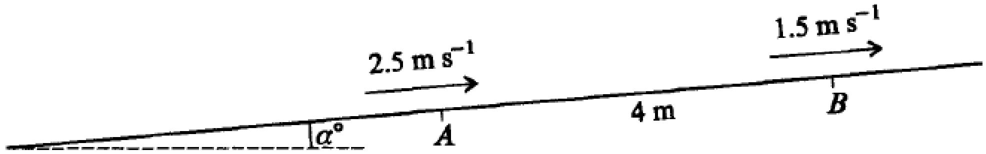
(ii) Show that $T - F > 0.32$, where T N is the tension in the string and F N is the magnitude of the frictional force on P. [4]

The coefficient of friction between P and the plane is 0.6.

(iii) Find the acceleration of P. [6]

(iii) 0.1

MAY/JUNE2007



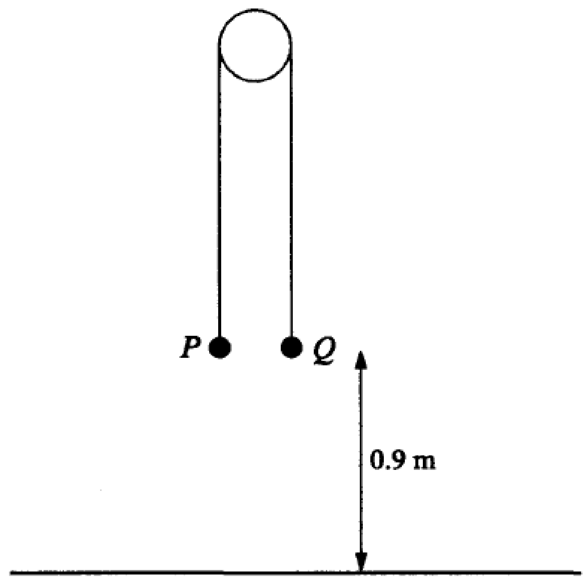
A particle slides up a line of greatest slope of a smooth plane inclined at an angle $\alpha°$ to the horizontal. The particle passes through the points A and B with speeds 2.5 m s^{-1} and 1.5 m s^{-1} respectively. The distance AB is 4 m (see diagram). Find

(i) the deceleration of the particle, [2]

(ii) the value of α. [2]

(i) 0.5
(ii) $2.9°$

MAY/JUNE2007



Particles P and Q, of masses 0.6 kg and 0.2 kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed peg. The particles are held at rest with the string taut. Both particles are at a height of 0.9 m above the ground (see diagram). The system is released and each of the particles moves vertically. Find

(i) the acceleration of P and the tension in the string before P reaches the ground, [5]

(ii) the time taken for P to reach the ground. [2]

(i) a = 5, T = 3
(ii) 0.6

OCTOBER/NOVEMBER2006

A cyclist travels along a straight road working at a constant rate of 420 W. The total mass of the cyclist and her cycle is 75 kg. Ignoring any resistance to motion, find the acceleration of the cyclist at an instant when she is travelling at 5 m s^{-1},

(i) given that the road is horizontal,

(ii) given instead that the road is inclined at $1.5°$ to the horizontal and the cyclist is travelling up the slope.

[5]

(i) 1.12
(ii) 0.858

OCTOBER/NOVEMBER2006

A particle of mass m kg moves up a line of greatest slope of a rough plane inclined at $21°$ to the horizontal. The frictional and normal components of the contact force on the particle have magnitudes F N and R N respectively. The particle passes through the point P with speed 10 m s^{-1}, and 2 s later it reaches its highest point on the plane.

(i) Show that $R = 9.336m$ and $F = 1.416m$, each correct to 4 significant figures. [5]

(ii) Find the coefficient of friction between the particle and the plane. [1]

After the particle reaches its highest point it starts to move down the plane.

(iii) Find the speed with which the particle returns to P. [5]

(ii) 0.152
(iii) 6.58

MAY/JUNE2006

A car of mass 1200 kg travels on a horizontal straight road with constant acceleration a m s^{-2}.

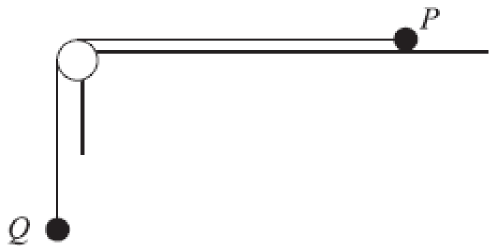
(i) Given that the car's speed increases from 10 m s^{-1} to 25 m s^{-1} while travelling a distance of 525 m, find the value of a. [2]

The car's engine exerts a constant driving force of 900 N. The resistance to motion of the car is constant and equal to R N.

(ii) Find R. [2]

(i) 0.5
(ii) 300

MAY/JUNE2006



Particles P and Q are attached to opposite ends of a light inextensible string. P is at rest on a rough horizontal table. The string passes over a small smooth pulley which is fixed at the edge of the table. Q hangs vertically below the pulley (see diagram). The force exerted on the string by the pulley has magnitude $4\sqrt{2}$ N. The coefficient of friction between P and the table is 0.8.

(i) Show that the tension in the string is 4 N and state the mass of Q. [2]

(ii) Given that P is on the point of slipping, find its mass. [2]

A particle of mass 0.1 kg is now attached to Q and the system starts to move.

(iii) Find the tension in the string while the particles are in motion. [4]

(i) 0.4
(ii) 0.5
(iii) 4.5

MAY/JUNE2006

Two particles P and Q move on a line of greatest slope of a smooth inclined plane. The particles start at the same instant and from the same point, each with speed $1.3\,\text{m s}^{-1}$. Initially P moves down the plane and Q moves up the plane. The distance between the particles t seconds after they start to move is d m.

(i) Show that $d = 2.6t$. [4]

When $t = 2.5$ the difference in the vertical height of the particles is 1.6 m. Find

(ii) the acceleration of the particles down the plane, [3]

(iii) the distance travelled by P when Q is at its highest point. [3]

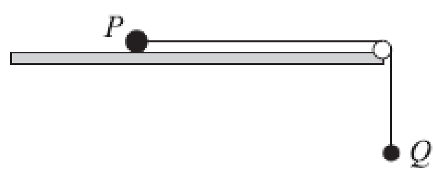
(ii) 2.46
(iii) 1.03

MAY/JUNE2005

A and B are points on the same line of greatest slope of a rough plane inclined at 30° to the horizontal. A is higher up the plane than B and the distance AB is 2.25 m. A particle P, of mass m kg, is released from rest at A and reaches B 1.5 s later. Find the coefficient of friction between P and the plane. [6]

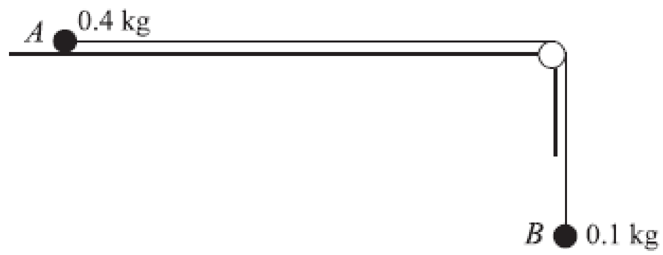
0.346

OCTOBER/NOVEMBER2004



Two particles P and Q, of masses 1.7 kg and 0.3 kg respectively, are connected by a light inextensible string. P is held on a smooth horizontal table with the string taut and passing over a small smooth pulley fixed at the edge of the table. Q is at rest vertically below the pulley. P is released. Find the acceleration of the particles and the tension in the string. [5]

a = 1.5, T = 2.55



Particles A and B, of masses 0.4 kg and 0.1 kg respectively, are attached to the ends of a light inextensible string. Particle A is held at rest on a horizontal table with the string passing over a smooth pulley at the edge of the table. Particle B hangs vertically below the pulley (see diagram). The system is released from rest. In the subsequent motion a constant frictional force of magnitude 0.6 N acts on A. Find

(i) the tension in the string, [4]

(ii) the speed of B 1.5 s after it starts to move. [3]

(i) 0.92
(ii) 1.2

MAY/JUNE2002

A box of mass 4.5 kg is pulled at a constant speed of $2\ \mathrm{m\,s^{-1}}$ along a rough horizontal floor by a horizontal force of magnitude 15 N.

(i) Find the coefficient of friction between the box and the floor. [3]

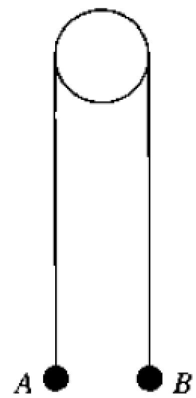
The horizontal pulling force is now removed. Find

(ii) the deceleration of the box in the subsequent motion, [2]

(iii) the distance travelled by the box from the instant the horizontal force is removed until the box comes to rest. [2]

(i) 0.333
(ii) -3.33
(iii) 0.6

MAY/JUNE2002



Particles A and B, of masses 0.15 kg and 0.25 kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. The system is held at rest with the string taut and with A and B at the same horizontal level, as shown in the diagram. The system is then released.

(i) Find the downward acceleration of B. [4]

After 2 s B hits the floor and comes to rest without rebounding. The string becomes slack and A moves freely under gravity.

(ii) Find the time that elapses until the string becomes taut again. [4]

(iii) Sketch on a single diagram the velocity-time graphs for both particles, for the period from their release until the instant that B starts to move upwards. [3]

(i) 2.5
(ii) 1

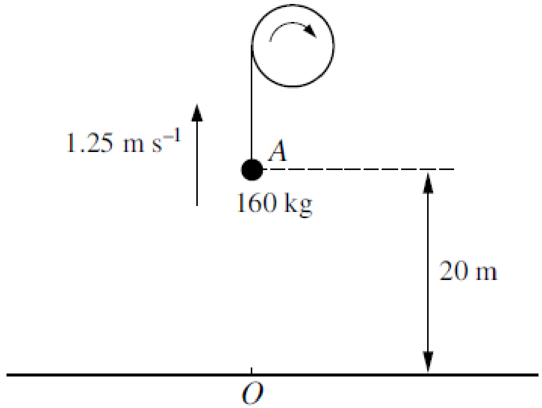
ENERGY, WORK & POWER

MAY/JUNE2012 9709/41

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 $16\,\mathrm{m\,s^{-1}}$ its acceleration is $0.625\,\mathrm{m\,s^{-2}}$. Find the value of P. [4]

20000

MAY/JUNE2012 9709/41



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]

(i) 32000
(ii) 125
(iii) 1250

MAY/JUNE2012 9709/42

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]

30

MAY/JUNE2012 9709/42

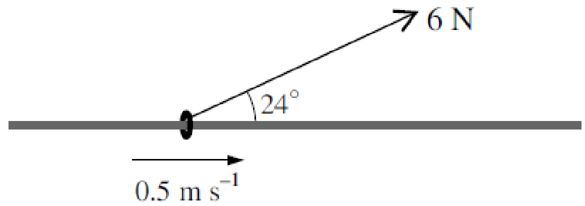
A car of mass 1250 kg travels from the bottom to the top of a straight hill which has length 400 m and is inclined to the horizontal at an angle of α, where $\sin\alpha = 0.125$. The resistance to the car's motion is 800 N. Find the work done by the car's engine in each of the following cases.

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

(ii) The car's initial speed is $6\,\text{m}\,\text{s}^{-1}$, 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]

(i) 945000
(ii) 985000

MAY/JUNE2012 9709/43



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 $0.5\,\mathrm{m\,s^{-1}}$. 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]

21.9

MAY/JUNE2012 9709/43

A lorry of mass 16 000 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 $20\,\mathrm{m\,s^{-1}}$ 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]

(i) 1.7
(ii) 30

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 $2\,\text{m}\,\text{s}^{-1}$. 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]

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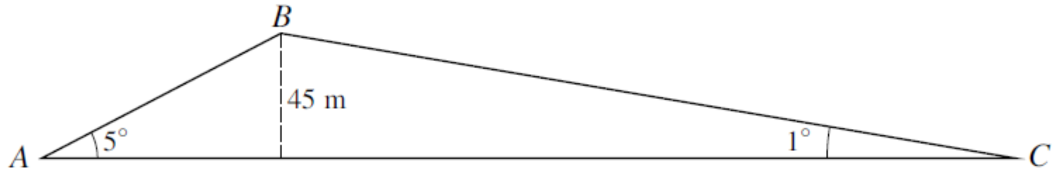


AB and BC are straight roads inclined at $5°$ to the horizontal and $1°$ to the horizontal respectively. A and C are at the same horizontal level and B is 45 m above the level of A and C (see diagram, which is not to scale). A car of mass 1200 kg travels from A to C passing through B.

(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 $15\,\mathrm{m\,s^{-1}}$, show that its speed at C is $29.9\,\mathrm{m\,s^{-1}}$, 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]

(i) 900000
(iii) 0.75

OCTOBER/NOVEMBER2011 9709/42

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 $0.16\,\mathrm{m\,s^{-2}}$ at an instant when his speed is $12\,\mathrm{m\,s^{-1}}$, find the value of R. [3]

(ii) Given that the cyclist's acceleration is positive, show that his speed is less than $15\,\mathrm{m\,s^{-1}}$. [2]

(i) 48

OCTOBER/NOVEMBER2011 9709/42

A lorry of mass 16 000 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.

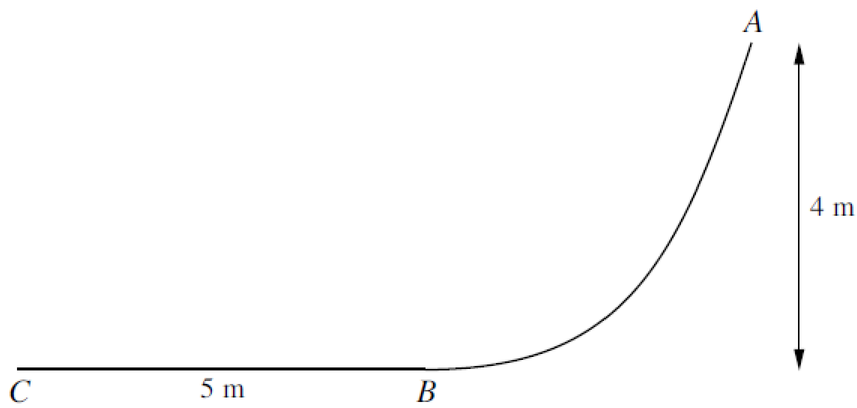
(ii) Find the distance BD. [1]

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]

(i) 200
(ii) 300
(iii) 61.3

OCTOBER/NOVEMBER2011 9709/43



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]

(i) 8.94
(ii) 7.07

OCTOBER/NOVEMBER2011 9709/43

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 $20\ \mathrm{m\,s^{-1}}$. 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 $30\ \mathrm{m\,s^{-1}}$. Find the distance CD. [4]

(i) 4000
(ii) 480
(iii) 360

MAY/JUNE2011 9709/41

A car of mass 700 kg is travelling along a straight horizontal road. The resistance to motion is constant and equal to 600 N.

(i) Find the driving force of the car's engine at an instant when the acceleration is $2\ \mathrm{m\,s^{-2}}$. [2]

(ii) Given that the car's speed at this instant is $15\ \mathrm{m\,s^{-1}}$, find the rate at which the car's engine is working. [2]

(i) 2000
(ii) 30000

MAY/JUNE2011 9709/41

A load of mass 1250 kg is raised by a crane from rest on horizontal ground, to rest at a height of 1.54 m above the ground. The work done against the resistance to motion is 5750 J.

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

(ii) Assuming the power output of the crane is constant and equal to 1.25 kW, find the time taken to raise the load. [2]

(i) 25000
(ii) 20

MAY/JUNE2011 9709/41

Loads A and B, of masses 1.2 kg and 2.0 kg respectively, are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. A is held at rest and B hangs freely, with both straight parts of the string vertical. A is released and starts to move upwards. It does not reach the pulley in the subsequent motion.

(i) Find the acceleration of A and the tension in the string. [4]

(ii) Find, for the first 1.5 metres of A's motion,

(a) A's gain in potential energy,

(b) the work done on A by the tension in the string,

(c) A's gain in kinetic energy.

[3]

B hits the floor 1.6 seconds after A is released. B comes to rest without rebounding and the string becomes slack.

(iii) Find the time from the instant the string becomes slack until it becomes taut again. [4]

(i) 15
(ii) (a) 18
(b) 22.5
(c) 4.5
(iii) 0.8

MAY/JUNE2011 9709/42

A load is pulled along horizontal ground for a distance of 76 m, using a rope. The rope is inclined at 5° above the horizontal and the tension in the rope is 65 N.

(i) Find the work done by the tension. [2]

At an instant during the motion the velocity of the load is $1.5\,\mathrm{m\,s^{-1}}$.

(ii) Find the rate of working of the tension at this instant. [2]

(i) 4920
(ii) 97.1

MAY/JUNE2011 9709/42

An object of mass 8 kg slides down a line of greatest slope of an inclined plane. Its initial speed at the top of the plane is $3\,\mathrm{m\,s^{-1}}$ and its speed at the bottom of the plane is $8\,\mathrm{m\,s^{-1}}$. The work done against the resistance to motion of the object is 120 J. Find the height of the top of the plane above the level of the bottom. [4]

4.25

MAY/JUNE2011 9709/43

A block is pulled for a distance of 50 m along a horizontal floor, by a rope that is inclined at an angle of $\alpha°$ to the floor. The tension in the rope is 180 N and the work done by the tension is 8200 J. Find the value of α. [3]

24.3

MAY/JUNE2011 9709/43

A car of mass 1250 kg is travelling along a straight horizontal road with its engine working at a constant rate of P W. The resistance to the car's motion is constant and equal to R N. When the speed of the car is $19\,\text{m}\,\text{s}^{-1}$ its acceleration is $0.6\,\text{m}\,\text{s}^{-2}$, and when the speed of the car is $30\,\text{m}\,\text{s}^{-1}$ its acceleration is $0.16\,\text{m}\,\text{s}^{-2}$. Find the values of P and R. [6]

R = 750, P = 28500

MAY/JUNE2011 9709/43

A lorry of mass 15 000 kg climbs a hill of length 500 m at a constant speed. The hill is inclined at 2.5° to the horizontal. The resistance to the lorry's motion is constant and equal to 800 N.

(i) Find the work done by the lorry's driving force. [4]

On its return journey the lorry reaches the top of the hill with speed 20 m s^{-1} and continues down the hill with a constant driving force of 2000 N. The resistance to the lorry's motion is again constant and equal to 800 N.

(ii) Find the speed of the lorry when it reaches the bottom of the hill. [5]

(i) 3670000
(ii) 30.3

OCTOBER/NOVEMBER2010 9709/41

A car of mass 600 kg travels along a horizontal straight road, with its engine working at a rate of 40 kW. The resistance to motion of the car is constant and equal to 800 N. The car passes through the point A on the road with speed 25 m s^{-1}. The car's acceleration at the point B on the road is half its acceleration at A. Find the speed of the car at B. [5]

33.3

OCTOBER/NOVEMBER2010 9709/41

A particle of mass 0.8 kg slides down a rough inclined plane along a line of greatest slope AB. The distance AB is 8 m. The particle starts at A with speed $3\ \mathrm{m\,s^{-1}}$ and moves with constant acceleration $2.5\ \mathrm{m\,s^{-2}}$.

(i) Find the speed of the particle at the instant it reaches B. [2]

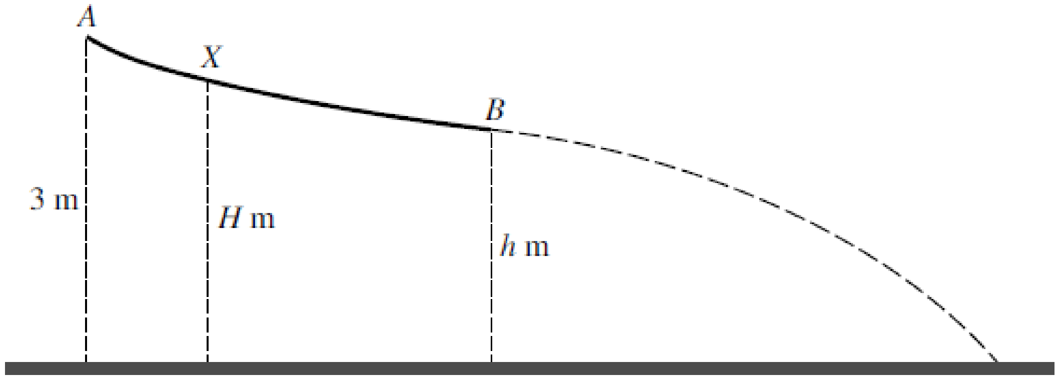
(ii) Given that the work done against the frictional force as the particle moves from A to B is 7 J, find the angle of inclination of the plane. [4]

When the particle is at the point X its speed is the same as the average speed for the motion from A to B.

(iii) Find the work done by the frictional force for the particle's motion from A to X. [3]

(i) 7
(ii) 21.1°
(iii) 2.8

OCTOBER/NOVEMBER2010 9709/41



A smooth slide AB is fixed so that its highest point A is 3 m above horizontal ground. B is h m above the ground. A particle P of mass 0.2 kg is released from rest at a point on the slide. The particle moves down the slide and, after passing B, continues moving until it hits the ground (see diagram). The speed of P at B is v_B and the speed at which P hits the ground is v_G.

(i) In the case that P is released at A, it is given that the kinetic energy of P at B is 1.6 J. Find

(a) the value of h, [3]

(b) the kinetic energy of the particle immediately before it reaches the ground, [1]

(c) the ratio $v_G : v_B$. [2]

(ii) In the case that P is released at the point X of the slide, which is H m above the ground (see diagram), it is given that $v_G : v_B = 2.55$. Find the value of H correct to 2 significant figures. [3]

(i) (a) 2.2

(b) 6

(c) 1.94

(ii) 2.6

OCTOBER/NOVEMBER2010 9709/42

A block of mass 20 kg is pulled from the bottom to the top of a slope. The slope has length 10 m and is inclined at 4.5° to the horizontal. The speed of the block is 2.5 m s^{-1} at the bottom of the slope and 1.5 m s^{-1} at the top of the slope.

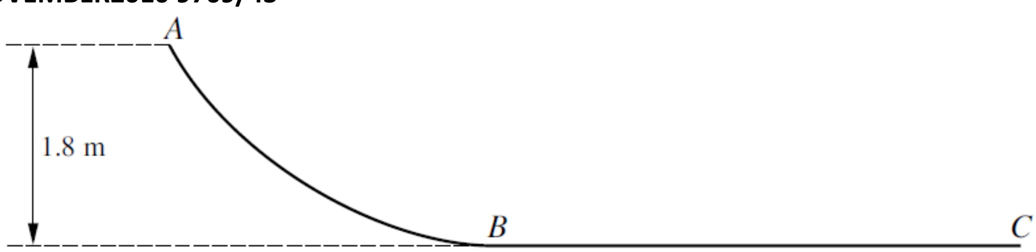
(i) Find the loss of kinetic energy and the gain in potential energy of the block. [3]

(ii) Given that the work done against the resistance to motion is 50 J, find the work done by the pulling force acting on the block. [2]

(iii) Given also that the pulling force is constant and acts at an angle of 15° upwards from the slope, find its magnitude. [2]

(i) PE gain = 157, KE loss = 40
(ii) 167
(iii) 17.3

OCTOBER/NOVEMBER2010 9709/43



The diagram shows the vertical cross-section ABC of a fixed surface. AB is a curve and BC is a horizontal straight line. The part of the surface containing AB is smooth and the part containing BC is rough. A is at a height of 1.8 m above BC. A particle of mass 0.5 kg is released from rest at A and travels along the surface to C.

(i) Find the speed of the particle at B. [2]

(ii) Given that the particle reaches C with a speed of 5 m s^{-1}, find the work done against the resistance to motion as the particle moves from B to C. [2]

(i) 6
(ii) 2.75

OCTOBER/NOVEMBER2010 9709/43

A car of mass 1250 kg travels along a horizontal straight road. The power of the car's engine is constant and equal to 24 kW and the resistance to the car's motion is constant and equal to R N. The car passes through the point A on the road with speed $20\,\mathrm{m\,s^{-1}}$ and acceleration $0.32\,\mathrm{m\,s^{-2}}$.

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

The car continues with increasing speed, passing through the point B on the road with speed $29.9\,\mathrm{m\,s^{-1}}$. The car subsequently passes through the point C.

(ii) Find the acceleration of the car at B, giving the answer in $\mathrm{m\,s^{-2}}$ correct to 3 decimal places. [2]

(iii) Show that, while the car's speed is increasing, it cannot reach $30\,\mathrm{m\,s^{-1}}$. [2]

(iv) Explain why the speed of the car is approximately constant between B and C. [1]

(v) State a value of the approximately constant speed, and the maximum possible error in this value at any point between B and C. [1]

The work done by the car's engine during the motion from B to C is 1200 kJ.

(vi) By assuming the speed of the car is constant from B to C, find, in either order,

(a) the approximate time taken for the car to travel from B to C,

(b) an approximation for the distance BC.

[4]

(i) 800
(ii) 0.002
(iv) $29.9 \leq v < 30$, speed approximately constant
(v) 30 (max error 0.1) or 29.95 (max error 0.05) or 29.9 (max error 0.1)
(vi) (a) 50
(b) 1500 or 1495

MAY/JUNE2010 9709/41

A car of mass 1150 kg travels up a straight hill inclined at 1.2° to the horizontal. The resistance to motion of the car is 975 N. Find the acceleration of the car at an instant when it is moving with speed $16\,\mathrm{m\,s^{-1}}$ and the engine is working at a power of 35 kW. [4]

0.845

MAY/JUNE2010 9709/41

P and Q are fixed points on a line of greatest slope of an inclined plane. The point Q is at a height of 0.45 m above the level of P. A particle of mass 0.3 kg moves upwards along the line PQ.

(i) Given that the plane is smooth and that the particle just reaches Q, find the speed with which it passes through P. [3]

(ii) It is given instead that the plane is rough. The particle passes through P with the same speed as that found in part **(i)**, and just reaches a point R which is between P and Q. The work done against the frictional force in moving from P to R is 0.39 J. Find the potential energy gained by the particle in moving from P to R and hence find the height of R above the level of P. [4]

(i) 3

(ii) PE gain = 0.96, 0.32m higher

MAY/JUNE2010 9709/43

A load is pulled along a horizontal straight track, from A to B, by a force of magnitude P N which acts at an angle of 30° upwards from the horizontal. The distance AB is 80 m. The speed of the load is constant and equal to $1.2\,\mathrm{m\,s^{-1}}$ as it moves from A to the mid-point M of AB.

(i) For the motion from A to M the value of P is 25. Calculate the work done by the force as the load moves from A to M. [2]

The speed of the load increases from $1.2\,\mathrm{m\,s^{-1}}$ as it moves from M towards B. For the motion from M to B the value of P is 50 and the work done against resistance is the same as that for the motion from A to M. The mass of the load is 35 kg.

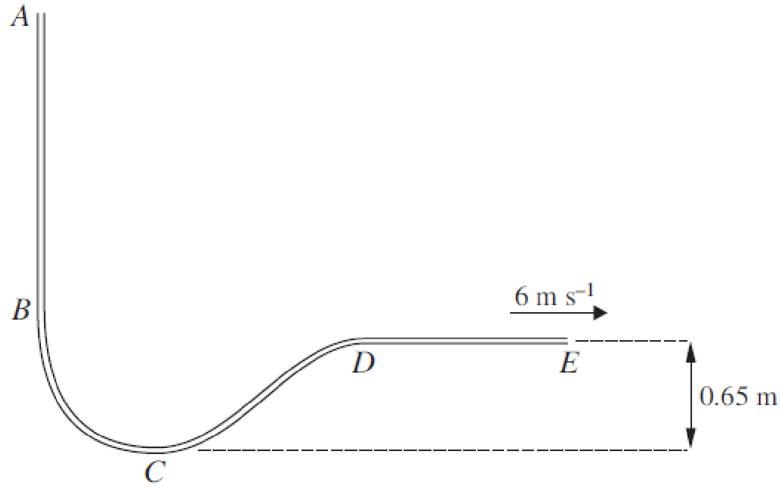
(ii) Find the gain in kinetic energy of the load as it moves from M to B and hence find the speed with which it reaches B. [5]

(i) 866
(ii) KE gain = 866, 7.14

OCTOBER/NOVEMBER2009 9709/41

A car of mass 1000 kg moves along a horizontal straight road, passing through points A and B. The power of its engine is constant and equal to 15 000 W. The driving force exerted by the engine is 750 N at A and 500 N at B. Find the speed of the car at A and at B, and hence find the increase in the car's kinetic energy as it moves from A to B. [4]

VA = 20, vB = 30
250000



A smooth narrow tube AE has two straight parts, AB and DE, and a curved part BCD. The part AB is vertical with A above B, and DE is horizontal. C is the lowest point of the tube and is 0.65 m below the level of DE. A particle is released from rest at A and travels through the tube, leaving it at E with speed $6\,\mathrm{m\,s^{-1}}$ (see diagram). Find

(i) the height of A above the level of DE, [2]

(ii) the maximum speed of the particle. [2]

(i) 1.8
(ii) 7

OCTOBER/NOVEMBER2009 9709/42

A lorry of mass 15 000 kg moves with constant speed 14 m s^{-1} from the top to the bottom of a straight hill of length 900 m. The top of the hill is 18 m above the level of the bottom of the hill. The total work done by the resistive forces acting on the lorry, including the braking force, is 4.8×10^6 J. Find

(i) the loss in gravitational potential energy of the lorry, [1]

(ii) the work done by the driving force. [1]

On reaching the bottom of the hill the lorry continues along a straight horizontal road against a constant resistance of 1600 N. There is no braking force acting. The speed of the lorry increases from 14 m s^{-1} at the bottom of the hill to 16 m s^{-1} at the point X, where X is 2500 m from the bottom of the hill.

(iii) By considering energy, find the work done by the driving force of the lorry while it travels from the bottom of the hill to X. [3]

(i) 2.7×10^6
(ii) 2.1×10^6
(iii) 4.45×10^6

OCTOBER/NOVEMBER2009 9709/42

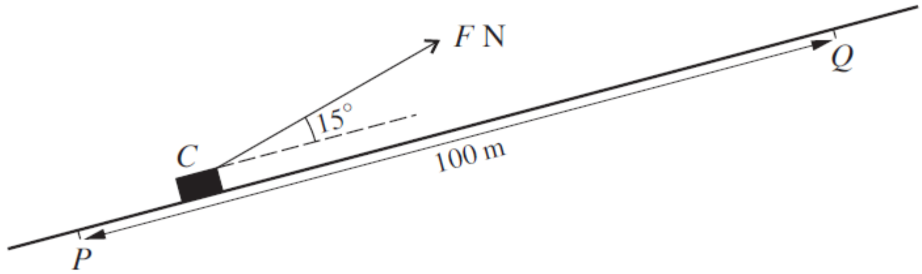
A car of mass 1250 kg travels along a horizontal straight road with increasing speed. The power provided by the car's engine is constant and equal to 24 kW. The resistance to the car's motion is constant and equal to 600 N.

(i) Show that the speed of the car cannot exceed 40 m s^{-1}. [3]

(ii) Find the acceleration of the car at an instant when its speed is 15 m s^{-1}. [3]

(ii) 0.8

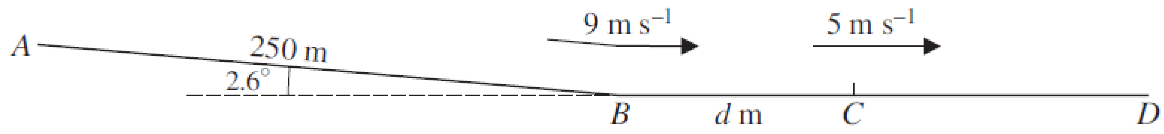
MAY/JUNE2009



A crate C is pulled at constant speed up a straight inclined path by a constant force of magnitude F N, acting upwards at an angle of 15° to the path. C passes through points P and Q which are 100 m apart (see diagram). As C travels from P to Q the work done against the resistance to C's motion is 900 J, and the gain in C's potential energy is 2100 J. Write down the work done by the pulling force as C travels from P to Q, and hence find the value of F. [3]

3000, 31.1

MAY/JUNE2009



A cyclist and his machine have a total mass of 80 kg. The cyclist starts from rest at the top A of a straight path AB, and freewheels (moves without pedalling or braking) down the path to B. The path AB is inclined at 2.6° to the horizontal and is of length 250 m (see diagram).

(i) Given that the cyclist passes through B with speed 9 m s^{-1}, find the gain in kinetic energy and the loss in potential energy of the cyclist and his machine. Hence find the work done against the resistance to motion of the cyclist and his machine. [3]

The cyclist continues to freewheel along a horizontal straight path BD until he reaches the point C, where the distance BC is d m. His speed at C is 5 m s^{-1}. The resistance to motion is constant, and is the same on BD as on AB.

(ii) Find the value of d. [3]

The cyclist starts to pedal at C, generating 425 W of power.

(iii) Find the acceleration of the cyclist immediately after passing through C. [3]

(i) KE gain = 3240, PE loss = 9070, Work done = 5830
(ii) 96.0
(iii) 0.771

OCTOBER/NOVEMBER2008

A car of mass 1200 kg is travelling on a horizontal straight road and passes through a point A with speed 25 m s^{-1}. The power of the car's engine is 18 kW and the resistance to the car's motion is 900 N.

(i) Find the deceleration of the car at A. [4]

(ii) Show that the speed of the car does not fall below 20 m s^{-1} while the car continues to move with the engine exerting a constant power of 18 kW. [2]

(i) 0.15

OCTOBER/NOVEMBER2008

A load of mass 160 kg is lifted vertically by a crane, with constant acceleration. The load starts from rest at the point O. After 7 s, it passes through the point A with speed 0.5 m s^{-1}. By considering energy, find the work done by the crane in moving the load from O to A. [6]

2820

MAY/JUNE2008

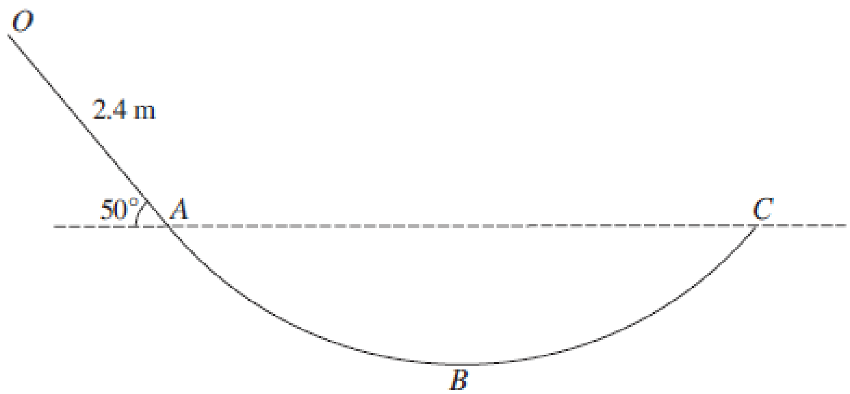
A block is being pulled along a horizontal floor by a rope inclined at 20° to the horizontal. The tension in the rope is 851 N and the block moves at a constant speed of $2.5\ \mathrm{m\,s^{-1}}$.

(i) Show that the work done on the block in 12 s is approximately 24 kJ. [3]

(ii) Hence find the power being applied to the block, giving your answer to the nearest kW. [1]

(ii) 2kW

MAY/JUNE2008



$OABC$ is a vertical cross-section of a smooth surface. The straight part OA has length 2.4 m and makes an angle of 50° with the horizontal. A and C are at the same horizontal level and B is the lowest point of the cross-section (see diagram). A particle P of mass 0.8 kg is released from rest at O and moves on the surface. P remains in contact with the surface until it leaves the surface at C. Find

(i) the kinetic energy of P at A, [2]

(ii) the speed of P at C. [2]

The greatest speed of P is $8\ \mathrm{m\,s^{-1}}$.

(iii) Find the depth of B below the horizontal through A and C. [3]

(i) 14.7
(ii) 6.06
(iii) 1.36

MAY/JUNE2008

A particle P of mass 0.6 kg is projected vertically upwards with speed 5.2 m s^{-1} from a point O which is 6.2 m above the ground. Air resistance acts on P so that its deceleration is 10.4 m s^{-2} when P is moving upwards, and its acceleration is 9.6 m s^{-2} when P is moving downwards. Find

(i) the greatest height above the ground reached by P, [3]

(ii) the speed with which P reaches the ground, [2]

(iii) the total work done on P by the air resistance. [4]

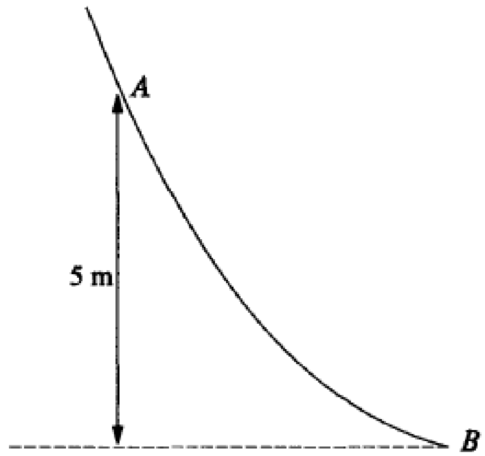
(i) 7.5
(ii) 12
(iii) 2.11

OCTOBER/NOVEMBER2007

A car of mass 900 kg travels along a horizontal straight road with its engine working at a constant rate of P kW. The resistance to motion of the car is 550 N. Given that the acceleration of the car is 0.2 m s^{-2} at an instant when its speed is 30 m s^{-1}, find the value of P. [4]

21.9

OCTOBER/NOVEMBER2007



The diagram shows the vertical cross-section of a surface. A and B are two points on the cross-section, and A is 5 m higher than B. A particle of mass 0.35 kg passes through A with speed 7 m s^{-1}, moving on the surface towards B.

(i) Assuming that there is no resistance to motion, find the speed with which the particle reaches B. [3]

(ii) Assuming instead that there is a resistance to motion, and that the particle reaches B with speed 11 m s^{-1}, find the work done against this resistance as the particle moves from A to B. [3]

(i) 12.2
(ii) 4.9

MAY/JUNE2007

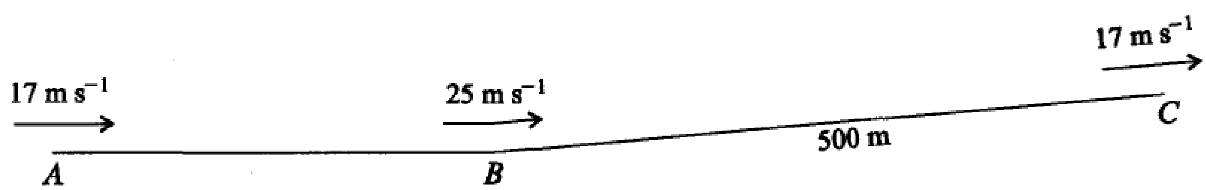
A car travels along a horizontal straight road with increasing speed until it reaches its maximum speed of $30\,\mathrm{m\,s^{-1}}$. The resistance to motion is constant and equal to R N, and the power provided by the car's engine is 18 kW.

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

(ii) Given that the car has mass 1200 kg, find its acceleration at the instant when its speed is $20\,\mathrm{m\,s^{-1}}$. [3]

(i) 600
(ii) 0.25

MAY/JUNE2007



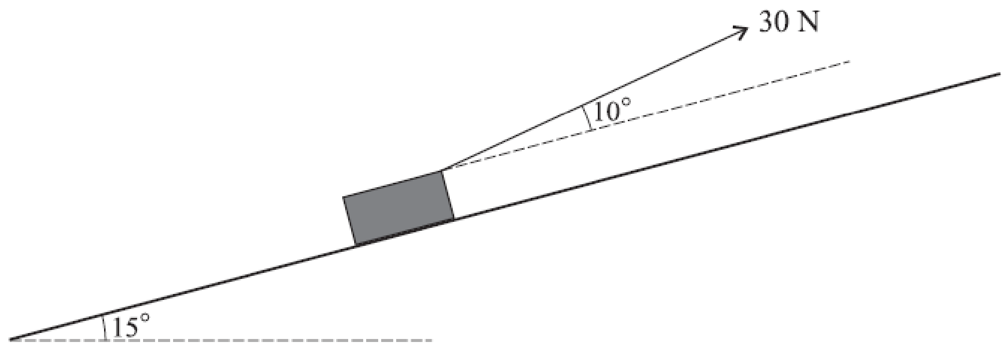
A lorry of mass 12 500 kg travels along a road that has a straight horizontal section AB and a straight inclined section BC. The length of BC is 500 m. The speeds of the lorry at A, B and C are $17\,\mathrm{m\,s^{-1}}$, $25\,\mathrm{m\,s^{-1}}$ and $17\,\mathrm{m\,s^{-1}}$ respectively (see diagram).

(i) The work done against the resistance to motion of the lorry, as it travels from A to B, is 5000 kJ. Find the work done by the driving force as the lorry travels from A to B. [4]

(ii) As the lorry travels from B to C, the resistance to motion is 4800 N and the work done by the driving force is 3300 kJ. Find the height of C above the level of AB. [4]

(i) 7100000
(ii)24

OCTOBER/NOVEMBER2006



A box of mass 8 kg is pulled, at constant speed, up a straight path which is inclined at an angle of 15° to the horizontal. The pulling force is constant, of magnitude 30 N, and acts upwards at an angle of 10° from the path (see diagram). The box passes through the points A and B, where $AB = 20$ m and B is above the level of A. For the motion from A to B, find

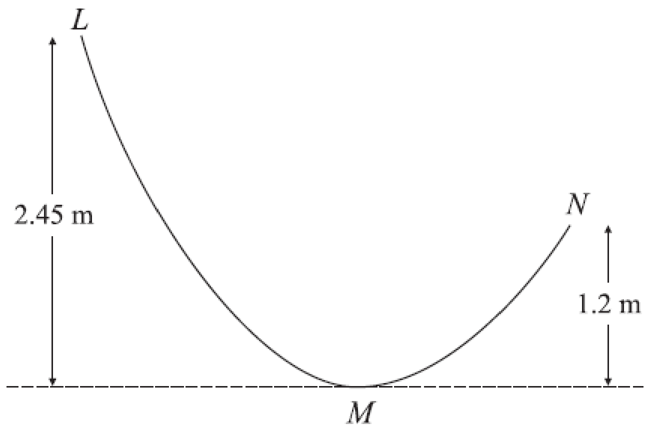
(i) the work done by the pulling force, [2]

(ii) the gain in potential energy of the box, [2]

(iii) the work done against the resistance to motion of the box. [1]

(i) 591
(ii) 414
(iii) 177

OCTOBER/NOVEMBER2006



The diagram shows the vertical cross-section LMN of a fixed smooth surface. M is the lowest point of the cross-section. L is 2.45 m above the level of M, and N is 1.2 m above the level of M. A particle of mass 0.5 kg is released from rest at L and moves on the surface until it leaves it at N. Find

(i) the greatest speed of the particle, [3]

(ii) the kinetic energy of the particle at N. [2]

The particle is now projected from N, with speed $v \text{ m s}^{-1}$, along the surface towards M.

(iii) Find the least value of v for which the particle will reach L. [2]

(i) 7
(ii) 6.25
(iii) 5

MAY/JUNE2006

A block of mass 50 kg is pulled up a straight hill and passes through points A and B with speeds $7\,\mathrm{m\,s^{-1}}$ and $3\,\mathrm{m\,s^{-1}}$ respectively. The distance AB is 200 m and B is 15 m higher than A. For the motion of the block from A to B, find

(i) the loss in kinetic energy of the block, [2]

(ii) the gain in potential energy of the block. [2]

The resistance to motion of the block has magnitude 7.5 N.

(iii) Find the work done by the pulling force acting on the block. [2]

The pulling force acting on the block has constant magnitude 45 N and acts at an angle $\alpha°$ upwards from the hill.

(iv) Find the value of α. [3]

(i) 1000
(ii) 7500
(iii) 8000
(iv) $27.3°$

OCTOBER/NOVEMBER2005

A crate of mass 50 kg is dragged along a horizontal floor by a constant force of magnitude 400 N acting at an angle $\alpha°$ upwards from the horizontal. The total resistance to motion of the crate has constant magnitude 250 N. The crate starts from rest at the point O and passes the point P with a speed of $2\ \text{m s}^{-1}$. The distance OP is 20 m. For the crate's motion from O to P, find

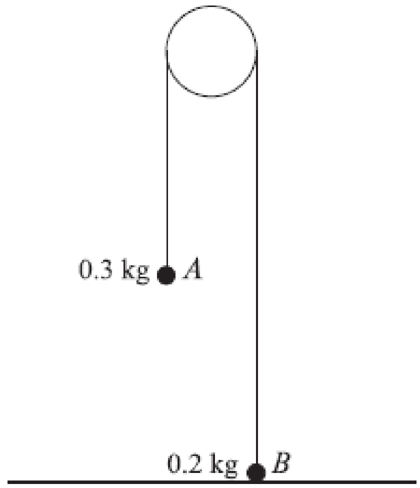
(i) the increase in kinetic energy of the crate, [1]

(ii) the work done against the resistance to the motion of the crate, [1]

(iii) the value of α. [3]

(i) 100
(ii) 5000
(iii) 50.4°

OCTOBER/NOVEMBER2005



Two particles A and B, of masses 0.3 kg and 0.2 kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. Particle B is held on the horizontal floor and particle A hangs in equilibrium. Particle B is released and each particle starts to move vertically with constant acceleration of magnitude a m s^{-2}.

(i) Find the value of a. [4]

Particle A hits the floor 1.2 s after it starts to move, and does not rebound upwards.

(ii) Show that A hits the floor with a speed of 2.4 m s^{-1}. [1]

(iii) Find the gain in gravitational potential energy by B, from leaving the floor until reaching its greatest height. [5]

(i) 2
(iii)3.456

MAY/JUNE2005

A small block is pulled along a rough horizontal floor at a constant speed of $1.5\,\mathrm{m\,s^{-1}}$ by a constant force of magnitude 30 N acting at an angle of $\theta°$ upwards from the horizontal. Given that the work done by the force in 20 s is 720 J, calculate the value of θ. [3]

36.9°

MAY/JUNE2005

A car of mass 1200 kg travels along a horizontal straight road. The power provided by the car's engine is constant and equal to 20 kW. The resistance to the car's motion is constant and equal to 500 N. The car passes through the points A and B with speeds $10\,\mathrm{m\,s^{-1}}$ and $25\,\mathrm{m\,s^{-1}}$ respectively. The car takes 30.5 s to travel from A to B.

(i) Find the acceleration of the car at A. [4]

(ii) By considering work and energy, find the distance AB. [8]

(i) 1.25
(ii) 590

OCTOBER/NOVEMBER2004

A car of mass 1250 kg travels down a straight hill with the engine working at a power of 22 kW. The hill is inclined at 3° to the horizontal and the resistance to motion of the car is 1130 N. Find the speed of the car at an instant when its acceleration is $0.2\,\mathrm{m\,s^{-2}}$. [5]

30.3

OCTOBER/NOVEMBER2004

A lorry of mass 16 000 kg climbs from the bottom to the top of a straight hill of length 1000 m at a constant speed of $10\ \mathrm{m\,s^{-1}}$. The top of the hill is 20 m above the level of the bottom of the hill. The driving force of the lorry is constant and equal to 5000 N. Find

(i) the gain in gravitational potential energy of the lorry, [1]

(ii) the work done by the driving force, [1]

(iii) the work done against the force resisting the motion of the lorry. [1]

On reaching the top of the hill the lorry continues along a straight horizontal road against a constant resistance of 1500 N. The driving force of the lorry is not now constant, and the speed of the lorry increases from $10\ \mathrm{m\,s^{-1}}$ at the top of the hill to $25\ \mathrm{m\,s^{-1}}$ at the point P. The distance of P from the top of the hill is 2000 m.

(iv) Find the work done by the driving force of the lorry while the lorry travels from the top of the hill to P. [5]

(i) 3.2×10^6
(ii) 5×10^6
(iii) 1.8×10^6
(iv) 7.2×10^6

MAY/JUNE2004

The top of an inclined plane is at a height of 0.7 m above the bottom. A block of mass 0.2 kg is released from rest at the top of the plane and slides a distance of 2.5 m to the bottom. Find the kinetic energy of the block when it reaches the bottom of the plane in each of the following cases:

(i) the plane is smooth, [2]

(ii) the coefficient of friction between the plane and the block is 0.15. [5]

(i) 1.4
(ii) 0.68

MAY/JUNE2004

A car of mass 1200 kg travels along a horizontal straight road. The power of the car's engine is 20 kW. The resistance to the car's motion is 400 N.

(i) Find the speed of the car at an instant when its acceleration is $0.5\,\mathrm{m\,s^{-2}}$. [4]

(ii) Show that the maximum possible speed of the car is $50\,\mathrm{m\,s^{-1}}$. [2]

The work done by the car's engine as the car travels from a point A to a point B is 1500 kJ.

(iii) Given that the car is travelling at its maximum possible speed between A and B, find the time taken to travel from A to B. [2]

(i) 20
(iii)75

OCTOBER/NOVEMBER2003

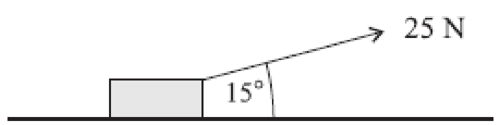
A motorcycle of mass 100 kg is travelling on a horizontal straight road. Its engine is working at a rate of 8 kW. At an instant when the speed of the motorcycle is 25 m s^{-1} its acceleration is 0.5 m s^{-2}. Find, at this instant,

(i) the force produced by the engine, [1]

(ii) the resistance to motion of the motorcycle. [3]

(i) 320
(ii) 270

OCTOBER/NOVEMBER2003



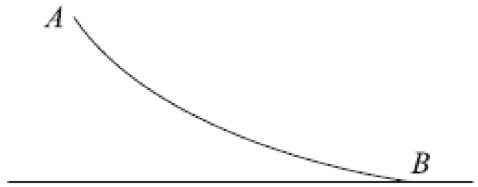
A crate of mass 3 kg is pulled at constant speed along a horizontal floor. The pulling force has magnitude 25 N and acts at an angle of 15° to the horizontal, as shown in the diagram. Find

(i) the work done by the pulling force in moving the crate a distance of 2 m, [2]

(ii) the normal component of the contact force on the crate. [3]

(i) 48.3
(ii) 23.5

OCTOBER/NOVEMBER2003



The diagram shows a vertical cross-section of a surface. A and B are two points on the cross-section. A particle of mass 0.15 kg is released from rest at A.

(i) Assuming that the particle reaches B with a speed of $8\,\mathrm{m\,s^{-1}}$ and that there are no resistances to motion, find the height of A above B. [3]

(ii) Assuming instead that the particle reaches B with a speed of $6\,\mathrm{m\,s^{-1}}$ and that the height of A above B is 4 m, find the work done against the resistances to motion. [3]

(i) 3.2
(ii) 3.3

MAY/JUNE2003

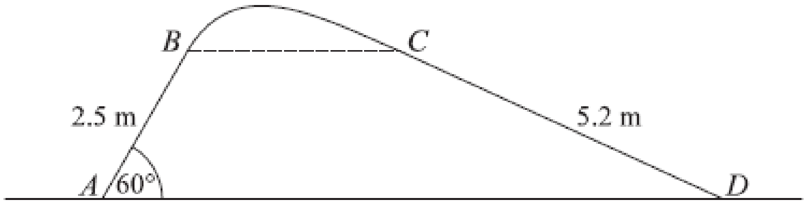
A crate of mass 800 kg is lifted vertically, at constant speed, by the cable of a crane. Find

(i) the tension in the cable, [1]

(ii) the power applied to the crate in increasing the height by 20 m in 50 s. [3]

(i) 8000
(ii) 3200

MAY/JUNE2003



The diagram shows a vertical cross-section $ABCD$ of a surface. The parts AB and CD are straight and have lengths 2.5 m and 5.2 m respectively. AD is horizontal, and AB is inclined at $60°$ to the horizontal. The points B and C are at the same height above AD. The parts of the surface containing AB and BC are smooth. A particle P is given a velocity of $8\,\mathrm{m\,s^{-1}}$ at A, in the direction AB, and it subsequently reaches D. The particle does not lose contact with the surface during this motion.

(i) Find the speed of P at B. [4]

(ii) Show that the maximum height of the cross-section, above AD, is less than 3.2 m. [2]

(iii) State briefly why P's speed at C is the same as its speed at B. [1]

(iv) The frictional force acting on the particle as it travels from C to D is 1.4 N. Given that the mass of P is 0.4 kg, find the speed with which P reaches D. [4]

(i) 4.55
(iii) Energy is conserved or absence of friction or curve BC is smooth and B and C are at the same height or the PE is the same at A and B.
(iv) 5.25

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A car of mass 1000 kg travels along a horizontal straight road with its engine working at a constant rate of 20 kW. The resistance to motion of the car is 600 N. Find the acceleration of the car at an instant when its speed is 25 m s^{-1}. [3]

0.2

OCTOBER/NOVEMBER2002

(i) A particle P of mass 1.2 kg is released from rest at the top of a slope and starts to move. The slope has length 4 m and is inclined at 25° to the horizontal. The coefficient of friction between P and the slope is $\frac{1}{4}$. Find

(a) the frictional component of the contact force on P, [2]

(b) the acceleration of P, [2]

(c) the speed with which P reaches the bottom of the slope. [2]

(ii) After reaching the bottom of the slope, P moves freely under gravity and subsequently hits a horizontal floor which is 3 m below the bottom of the slope.

(a) Find the loss in gravitational potential energy of P during its motion from the bottom of the slope until it hits the floor. [1]

(b) Find the speed with which P hits the floor. [3]

(i) (a) 2.72
(b) 1.96
(c) 3.96
(ii) (a) 36
(b) 8.70

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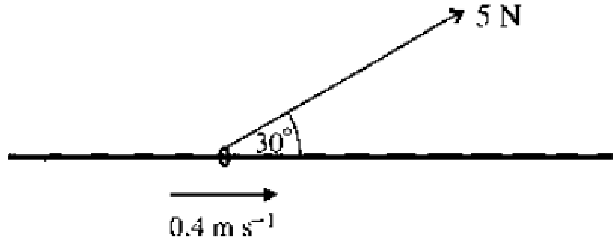

One end of a light inextensible string is attached to a ring which is threaded on a fixed horizontal bar. The string is used to pull the ring along the bar at a constant speed of $0.4\,\mathrm{m\,s^{-1}}$. The string makes a constant angle of $30°$ with the bar and the tension in the string is 5 N (see diagram). Find the work done by the tension in 10 s. [3]

17.3

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(i) A lorry P of mass 15 000 kg climbs a straight hill of length 800 m at a steady speed. The hill is inclined at $2°$ to the horizontal. For P's journey from the bottom of the hill to the top, find

(a) the gain in gravitational potential energy, [2]

(b) the work done by the driving force, which has magnitude 7000 N, [1]

(c) the work done against the force resisting the motion. [2]

(ii) A second lorry, Q, also has mass 15 000 kg and climbs the same hill as P. The motion of Q is subject to a constant resisting force of magnitude 900 N, and Q's speed falls from $20\,\mathrm{m\,s^{-1}}$ at the bottom of the hill to $10\,\mathrm{m\,s^{-1}}$ at the top. Find the work done by the driving force as Q climbs from the bottom of the hill to the top. [5]

(i) (a) 4190000
(b) 5600000
(c) 1410000
(ii) 2660000