1 An athlete has mass m kg. The athlete runs along a horizontal road against a constant resistance force of magnitude 24 N. The total work done by the athlete in increasing his speed from $5\,\text{m}\,\text{s}^{-1}$ to $6\,\text{m}\,\text{s}^{-1}$ while running a distance of 50 metres is 1541 J.

Find the value of m. [4]

1 A block of mass 15 kg slides down a line of greatest slope of an inclined plane. The top of the plane is at a vertical height of 1.6 m above the level of the bottom of the plane. The speed of the block at the top of the plane is $2\,m\,s^{-1}$ and the speed of the block at the bottom of the plane is $4\,m\,s^{-1}$.

Find the work done against the resistance to motion of the block. [4]

1 A cyclist and bicycle have a total mass of 72 kg. The cyclist rides along a horizontal road against a total resistance force of 28 N.

Find the total work done by the cyclist to increase his speed from $8\,m\,s^{-1}$ to $16\,m\,s^{-1}$ while travelling a distance of 100 metres. [3]

1 A particle of mass 1.6 kg is dropped from a height of 9 m above horizontal ground. The speed of the particle at the instant before hitting the ground is $12\,\text{m}\,\text{s}^{-1}$.

Find the work done against air resistance. [3]

1 A cyclist is riding a bicycle along a straight horizontal road AB of length 50 m. The cyclist starts from rest at A and reaches a speed of $6\,\text{m}\,\text{s}^{-1}$ at B. The cyclist produces a constant driving force of magnitude 100 N. There is a resistance force, and the work done against the resistance force from A to B is 3560 J.

Find the total mass of the cyclist and bicycle. [3]

1 A winch operates by means of a force applied by a rope. The winch is used to pull a load of mass 50 kg up a line of greatest slope of a plane inclined at 60° to the horizontal. The winch pulls the load a distance of 5 m up the plane at constant speed. There is a constant resistance to motion of 100 N.

Find the work done by the winch. [3]

1 A particle of mass 0.6 kg is projected with a speed of $4\ \text{m s}^{-1}$ down a line of greatest slope of a smooth plane inclined at 10° to the horizontal.

Use an energy method to find the speed of the particle after it has moved 15 m down the plane. [3]

1 A particle of mass 1.6 kg is projected with a speed of $20\,\text{m}\,\text{s}^{-1}$ up a line of greatest slope of a smooth plane inclined at α to the horizontal, where $\tan\alpha = \frac{3}{4}$.

Use an energy method to find the distance the particle moves up the plane before coming to instantaneous rest. [3]

2 A block of mass 20 kg is held at rest at the top of a plane inclined at 30° to the horizontal. The block is projected with speed $5\,m\,s^{-1}$ down a line of greatest slope of the plane. There is a resistance force acting on the block. As the block moves 2 m down the plane from its point of projection, the work done against this resistance force is 50 J.

Find the speed of the block when it has moved 2 m down the plane. [4]

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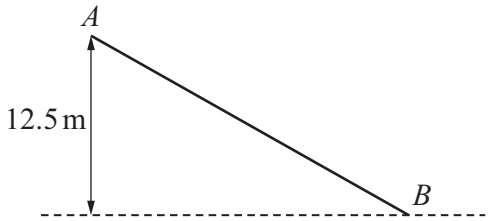

A particle of mass 7.5 kg, starting from rest at A, slides down an inclined plane AB. The point B is 12.5 metres vertically below the level of A, as shown in the diagram.

(a) Given that the plane is smooth, use an energy method to find the speed of the particle at B. [2]

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(b) It is given instead that the plane is rough and the particle reaches B with a speed of $8\,\text{m}\,\text{s}^{-1}$. The plane is 25 m long and the constant frictional force has magnitude F N.

Find the value of F. [3]

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3 A train of mass 180 000 kg ascends a straight hill of length 1.5 km, inclined at an angle of 1.5° to the horizontal. As it ascends the hill, the total work done to overcome the resistance to motion is 12 000 kJ and the speed of the train decreases from $45\,m\,s^{-1}$ to $40\,m\,s^{-1}$.

Find the work done by the engine of the train as it ascends the hill, giving your answer in kJ. [4]

2 A particle P of mass 0.4 kg is projected vertically upwards from horizontal ground with speed $10\,\text{m}\,\text{s}^{-1}$.

(a) Find the greatest height above the ground reached by P. [2]

When P reaches the ground again, it bounces vertically upwards. At the first instant that it hits the ground, P loses 7.2 J of energy.

(b) Find the time between the first and second instants at which P hits the ground. [4]

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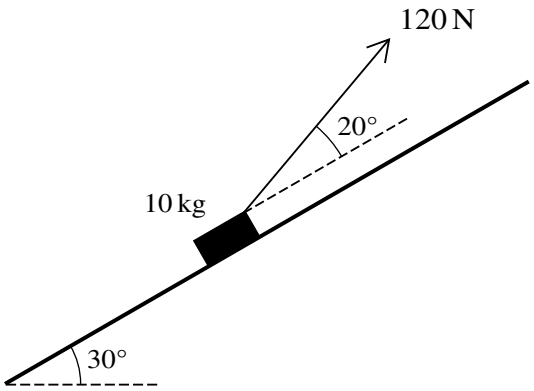

A block of mass 10 kg is at rest on a rough plane inclined at an angle of 30° to the horizontal. A force of 120 N is applied to the block at an angle of 20° above a line of greatest slope (see diagram). There is a force resisting the motion of the block and 200 J of work is done against this force when the block has moved a distance of 5 m up the plane from rest.

Find the speed of the block when it has moved a distance of 5 m up the plane from rest. [5]

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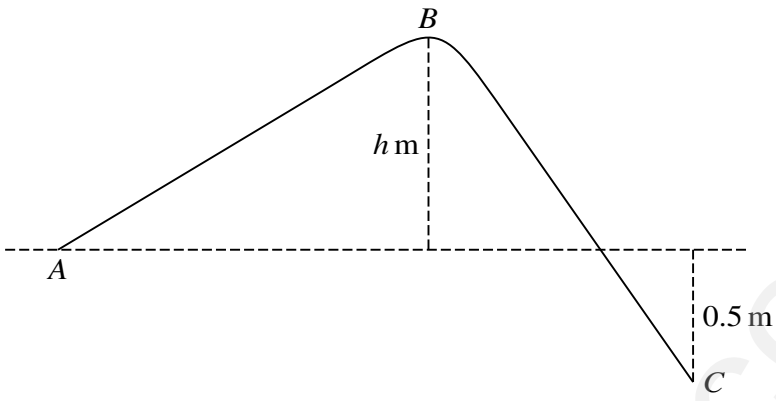

The diagram shows the vertical cross-section of a surface. A, B and C are three points on the cross-section. The level of B is h m above the level of A. The level of C is 0.5 m below the level of A. A particle of mass 0.2 kg is projected up the slope from A with initial speed 5 m s^{-1}. The particle remains in contact with the surface as it travels from A to C.

(a) Given that the particle reaches B with a speed of 3 m s^{-1} and that there is no resistance force, find h. [3]

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(b) It is given instead that there is a resistance force and that the particle does 3.1 J of work against the resistance force as it travels from A to C.

Find the speed of the particle when it reaches C. [3]

2 A box of mass 5 kg is pulled at a constant speed a distance of 15 m up a rough plane inclined at an angle of 20° to the horizontal. The box moves along a line of greatest slope against a frictional force of 40 N. The force pulling the box is parallel to the line of greatest slope.

(a) Find the work done against friction. [1]

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(b) Find the change in gravitational potential energy of the box. [2]

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(c) Find the work done by the pulling force. [1]

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2 A box of mass 5 kg is pulled at a constant speed of $1.8\,\text{m}\,\text{s}^{-1}$ for 15 s up a rough plane inclined at an angle of 20° to the horizontal. The box moves along a line of greatest slope against a frictional force of 40 N. The force pulling the box is parallel to the line of greatest slope.

(a) Find the change in gravitational potential energy of the box. [2]

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(b) Find the work done by the pulling force. [2]

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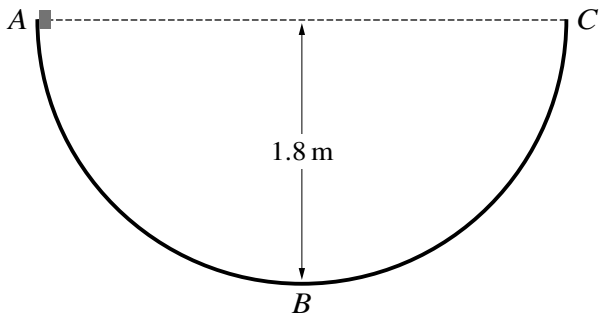

The diagram shows a semi-circular track ABC of radius 1.8 m which is fixed in a vertical plane. The points A and C are at the same horizontal level and the point B is at the bottom of the track. The section AB is smooth and the section BC is rough. A small block is released from rest at A.

(a) Show that the speed of the block at B is $6\,\text{m}\,\text{s}^{-1}$. [2]

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The block comes to instantaneous rest for the first time at a height of 1.2 m above the level of B. The work done against the resistance force during the motion of the block from B to this point is 4.5 J.

(b) Find the mass of the block. [3]

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3 A ball of mass 1.6 kg is released from rest at a point 5 m above horizontal ground. When the ball hits the ground it instantaneously loses 8 J of kinetic energy and starts to move upwards.

(a) Use an energy method to find the greatest height that the ball reaches after hitting the ground. [3]

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(b) Find the total time taken, from the initial release of the ball until it reaches this greatest height. [3]

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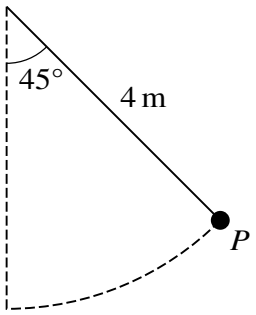

A child of mass 35 kg is swinging on a rope. The child is modelled as a particle P and the rope is modelled as a light inextensible string of length 4 m. Initially P is held at an angle of 45° to the vertical (see diagram).

(a) Given that there is no resistance force, find the speed of P when it has travelled half way along the circular arc from its initial position to its lowest point. [4]

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(b) It is given instead that there is a resistance force. The work done against the resistance force as P travels from its initial position to its lowest point is X J. The speed of P at its lowest point is $4\,\text{m}\,\text{s}^{-1}$.

Find X. [3]

5 A block B of mass 4 kg is pushed up a line of greatest slope of a smooth plane inclined at 30° to the horizontal by a force applied to B, acting in the direction of motion of B. The block passes through points P and Q with speeds 12 m s^{-1} and 8 m s^{-1} respectively. P and Q are 10 m apart with P below the level of Q.

(a) Find the decrease in kinetic energy of the block as it moves from P to Q. [2]

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(b) Hence find the work done by the force pushing the block up the slope as the block moves from P to Q. [3]

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(c) At the instant the block reaches Q, the force pushing the block up the slope is removed.

Find the time taken, after this instant, for the block to return to P. [4]

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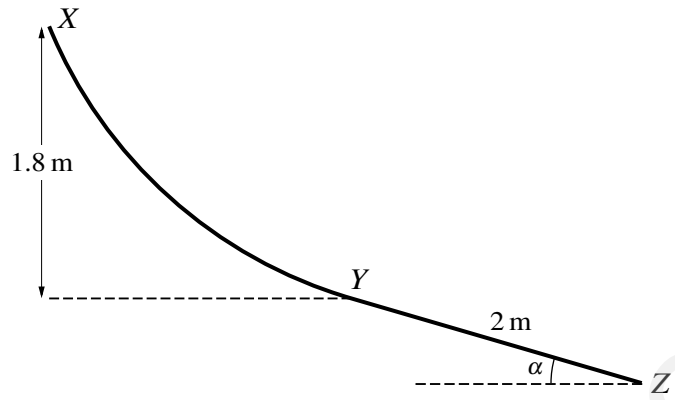

The diagram shows the vertical cross-section XYZ of a rough slide. The section YZ is a straight line of length 2 m inclined at an angle of α to the horizontal, where $\sin \alpha = 0.28$. The section YZ is tangential to the curved section XY at Y, and X is 1.8 m above the level of Y. A child of mass 25 kg slides down the slide, starting from rest at X. The work done by the child against the resistance force in moving from X to Y is 50 J.

(a) Find the speed of the child at Y. [4]

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It is given that the child comes to rest at Z.

(b) Use an energy method to find the coefficient of friction between the child and YZ, giving your answer as a fraction in its simplest form. [6]

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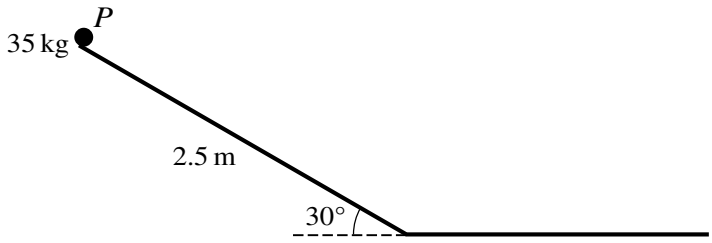

A slide in a playground descends at a constant angle of 30° for 2.5 m. It then has a horizontal section in the same vertical plane as the sloping section. A child of mass 35 kg, modelled as a particle P, starts from rest at the top of the slide and slides straight down the sloping section. She then continues along the horizontal section until she comes to rest (see diagram). There is no instantaneous change in speed when the child goes from the sloping section to the horizontal section.

The child experiences a resistance force on the horizontal section of the slide, and the work done against the resistance force on the horizontal section of the slide is 250 J per metre.

(a) It is given that the sloping section of the slide is smooth.

(i) Find the speed of the child when she reaches the bottom of the sloping section. [3]

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(ii) Find the distance that the child travels along the horizontal section of the slide before she comes to rest. [2]

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(b) It is given instead that the sloping section of the slide is rough and that the child comes to rest on the slide 1.05 m after she reaches the horizontal section.

Find the coefficient of friction between the child and the sloping section of the slide. [6]