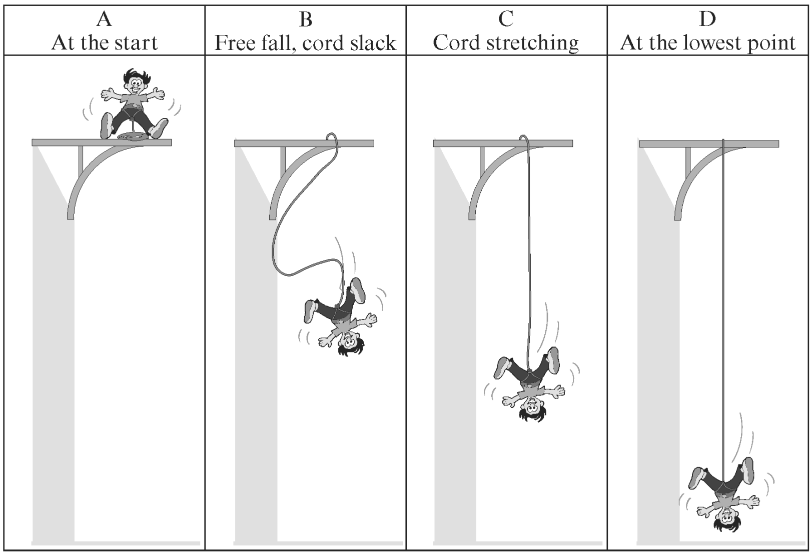
1.

(a) By referring to the diagrams, discuss some of the energy changes involved in a bungee jump. You should make reference to *gravitational potential energy*, *kinetic energy* and *elastic potential energy* in your answer. [5]



(b) A bungee jumper of mass 70 kg jumps from a high bridge using a bungee cord of natural length 80 m. When he reaches the lowest point for the first time the length of the cord is 130 m. Calculate

(i) the loss of gravitational potential energy from his position on the bridge to the lowest point for the first time, [2]

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(ii) the stiffness constant *(k)* of the bungee cord assuming the cord obeys Hooke's law and that there are no losses due to air resistance, [3]

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(iii) the extension of the cord when he finally comes to rest (after having 'bounced' a few times). [2]

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2.

2. A wooden block on a string (ballistic pendulum) is a device that can be found at well equipped shooting ranges. It is used to find the speed of a bullet. To calculate the speed it is necessary to use both the principles of conservation of energy and momentum.

(a) State the principle of conservation of energy. [1]

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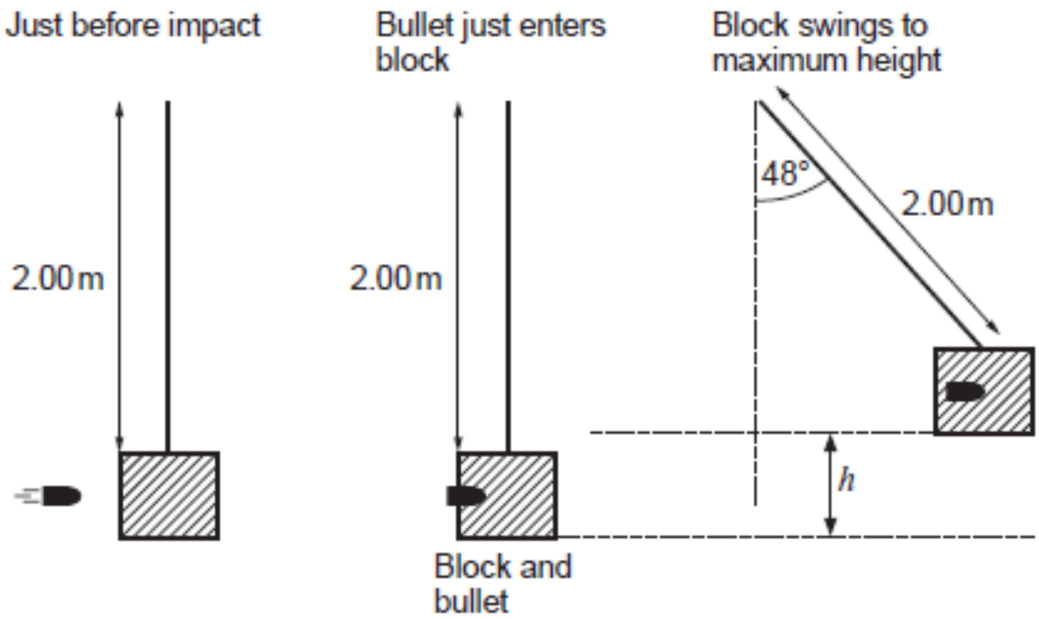
(b) When a bullet of mass 10.0 g is fired horizontally into a pendulum of mass 1.90 kg, the block rises through an angle of 48° as shown. The pendulum string is 2.00 metres long.



(i) Show that the height, h, the block rises is approximately 0.70 m. [2]

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(ii) Using the principle of conservation of energy, determine the velocity of the block **and** the bullet just after the bullet has embedded itself in the block. [2]

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(c) (i) State the principle of conservation of momentum. [2]

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(ii) Determine the speed of the bullet just before it enters the block. [2]

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(d) Discuss whether you feel it would be appropriate for a Physics teacher to carry out this experiment in school with a group of sixth form students. [2]

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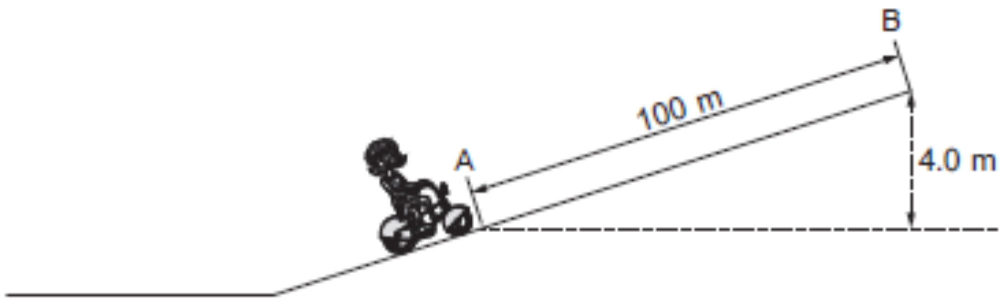
3.

3. Helen is riding an electric bike (a bike that is assisted by an electric motor) up a hill at a speed of $4.5\,\text{m s}^{-1}$. At point A she starts the electric motor and accelerates uniformly reaching a speed of $9.2\,\text{m s}^{-1}$ at B. Whilst accelerating she also gains a height of 4.0 m as shown in the diagram below.



(a) Show that the time taken for Helen's journey between A and B is approximately 15 s. [2]

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(b) Helen and the bike have a combined mass of 95 kg. Determine the gain in total energy between A and B. [3]

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(c) (i) If the bike's electric motor operates at 36 V and 7.0 A calculate the electrical energy used by the motor between A and B. [2]

(ii) Helen, by pedalling, also provides 5 500 J of work between A and B. Determine the efficiency of the electric motor. *Ignore all resistive forces on Helen and the bike.* [2]

(iii) In practice resistive forces will act. Identify these forces and where they act. [2]

(d) Helen believes that by riding an electrically powered bike to the shops rather than using her car she is benefiting the environment. Explain whether or not Helen is correct. [2]

4.

4. (a) State the *principle of conservation of energy.* [2]

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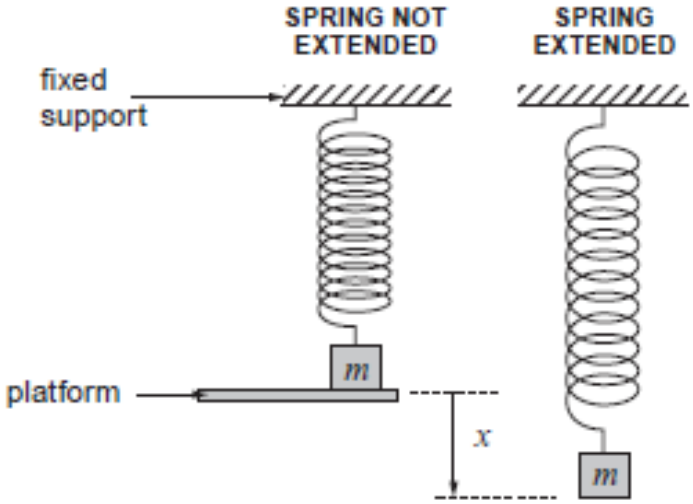
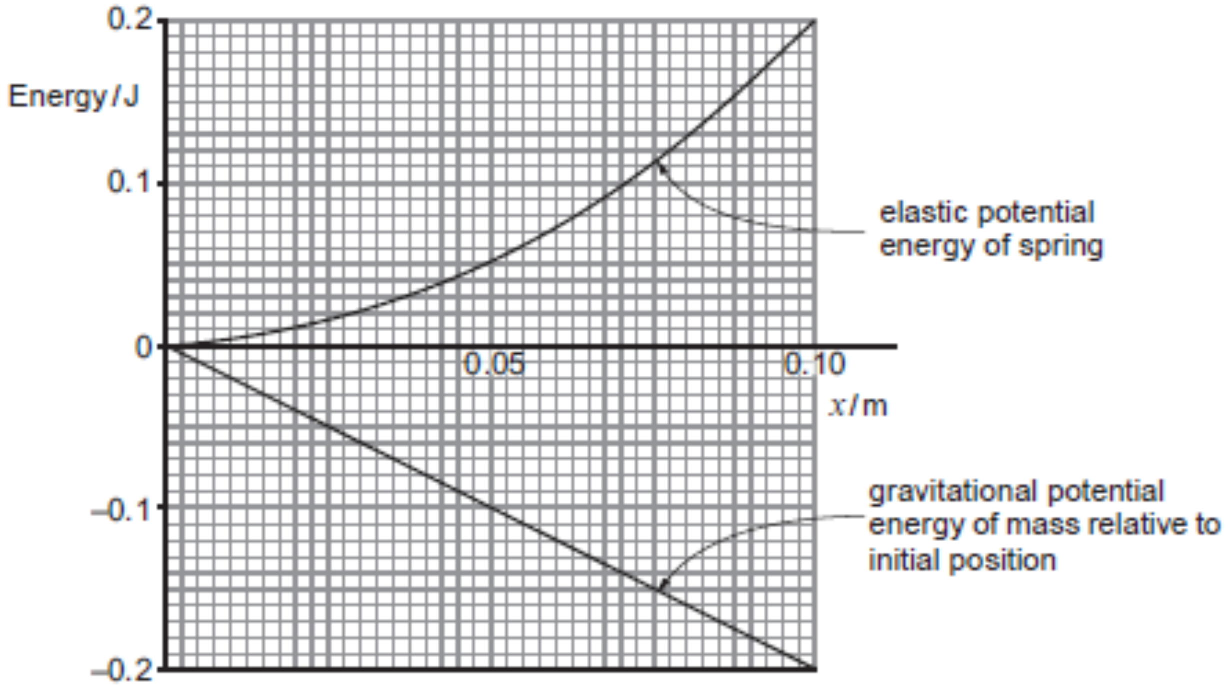
(b) A mass, m, is attached to a light spring whose top end is held firmly. Initially the mass is supported by a platform with the spring unextended. The platform is suddenly removed so the mass falls.



The graphs show how the elastic potential energy of the spring and the gravitational potential energy of the mass vary with the distance, x, of the mass below the platform (see diagrams).



(i) Assuming that resistive forces are negligible, use data from the graphs to calculate:

I. the spring constant, k; [3]

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II. the mass, m; [2]

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III. the kinetic energy of m when x = 0.050 m. [2]

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(ii) Sketch a graph of the kinetic energy of the mass, m, against x **on the same grid as the other graphs**. [2]

(c) In the arrangement described in *(b)*, the furthest distance, x_{max}, that m falls is 0.10 m. However, a larger mass would fall further. In theory, x_{max} is directly proportional to the mass, m. Describe briefly how you would verify this relationship by experiment. [4]

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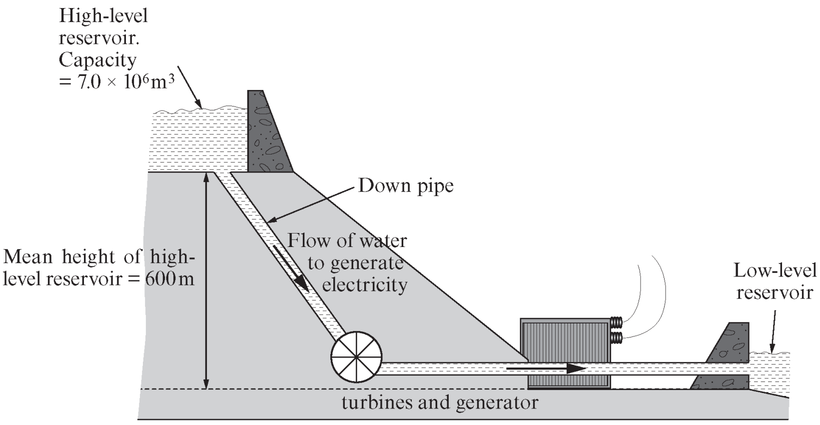
5.

The hydroelectric power station at Dinorwig in North Wales is the largest of its kind in Europe. A simplified diagram showing the main features of the plant is shown.



(a) Use the information in the diagram to show that the gravitational potential energy stored in the high-level reservoir is approximately 4×10^{13} J.
[Density of water = 1000 kg m^{-3}]. [2]

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(b) The power plant has six 300 MW generators. Calculate the longest time for which the stored energy could provide power at maximum output given that the generation process is 90% efficient [i.e. 10% of the gravitational potential energy stored in the high level reservoir is wasted]. [3]

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(c) (i) Calculate the mean rate of flow of water (in kg s^{-1}) through the turbines of the power station when it is operating at full power. [1]

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(ii) After passing through the turbines the water enters the lower lake at a speed of $20\,m\,s^{-1}$. Use your answer to *(c)*(i) to calculate the kinetic energy per second [power] of this water. [1]

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(iii) Calculate the **wasted energy per second** (power lost) during the generation process. [2]

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(iv) Hence show that your answer to *(c)*(ii) represents between 30% and 40% of the wasted power. [1]

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(v) Where else would energy be wasted during the generating process? [1]

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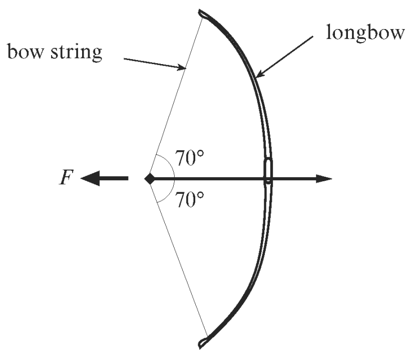
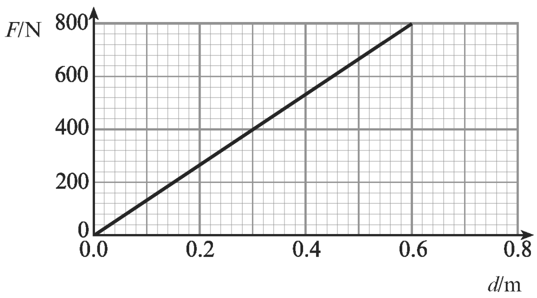
6.

(a) The medieval longbow was a devastatingly effective weapon. Assuming that a horizontal force F of 800 N is needed to draw back the bow string, show that the tension T in the string is approximately 1170 N. [2]

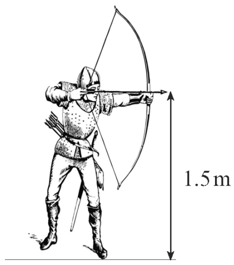


(b) (i) The graph shows the variation of F with d for the longbow, where d is the distance the centre of the string is pulled back. Calculate the energy stored in the bow when the tension in the string is 1170 N. [2]



(ii) Hence, **stating any assumptions you make**, show that the speed of the arrow as it leaves the bow is about $100\,\mathrm{m\,s^{-1}}$. Take the mass of the arrow to be 50×10^{-3} kg. [3]

(c) The arrow is released horizontally at this speed from 1.5 m above the ground as shown. The arrow continues its path until it embeds itself into the ground a horizontal distance *D* from the point of release. **Ignoring the effects of air on the arrow**, calculate



(i) the time taken for the arrow to reach the ground, [3]

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(ii) the horizontal distance *D*, [2]

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(iii) the **resultant velocity** of the arrow when it hits the ground. [5]

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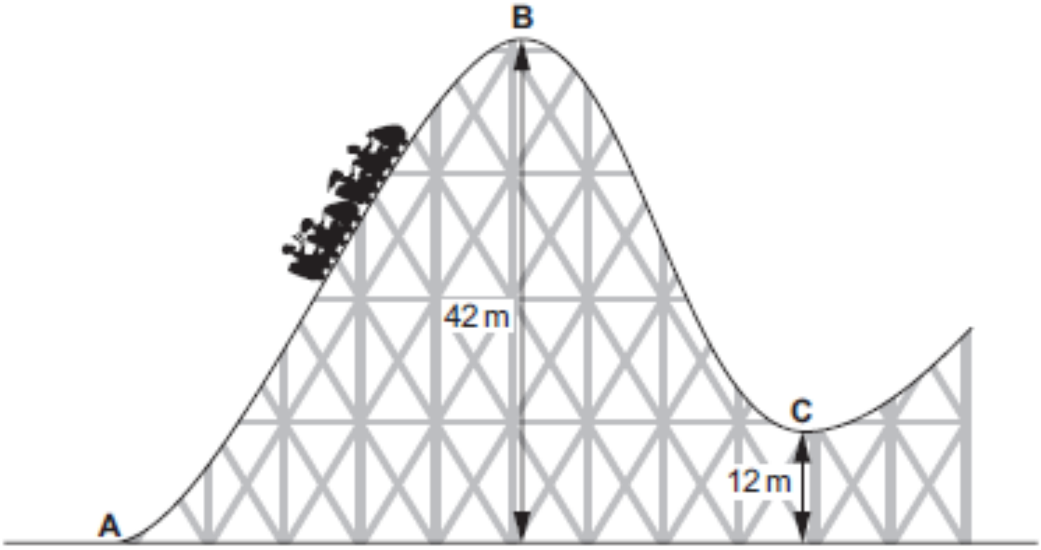
7.

7. The diagram shows part of a rollercoaster ride at a theme park.



(a) A motor with a power output of 65 kW and a chain mechanism pulls the carriages of mass 2 600 kg from A to B in a time of 32 s.

(i) Show that the work done by the motor in 32 seconds is approximately 2 MJ. [1]

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(ii) Hence calculate the efficiency of the mechanism, assuming the carriages are momentarily at rest at B. [3]

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(b) At B, the carriages become disconnected from the motor and the carriages move under the influence of gravity for the rest of the ride. In moving from B to C, a distance along the track of 36 m, the carriages experience a mean resistive force of 2.8 kN. Calculate the speed of the carriages at C. [5]

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8.

1. *(a)* (i) State the principle of conservation of energy. [1]

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(ii) Explain how the principle applies to an object falling from rest **through the air**. [3]

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(b) A child of mass 16 kg starts from rest at the top of a playground slide and reaches the bottom of the slide with a speed of 6.0 m s^{-1}. The slide is 4.0 m long and there is a difference in height of 2.4 m between the top and the bottom.

(i) Calculate the work done against friction. [3]

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(ii) Use your answer to *(b)*(i) to calculate the mean frictional force acting on the child. [2]

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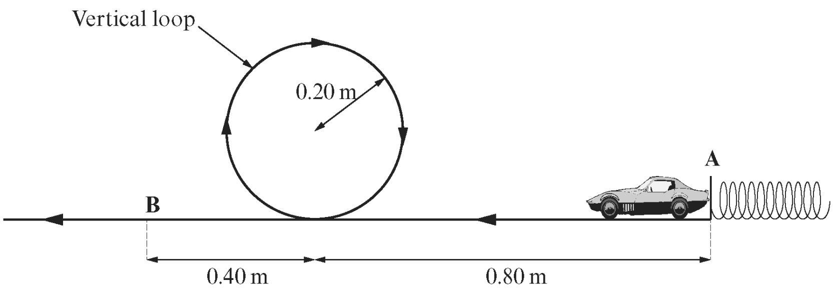
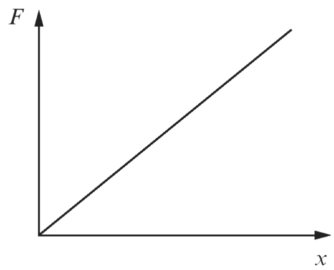
9. A compressed spring is used to shoot a small toy car along a track which contains a circular vertical loop of radius 0.20 m. The spring obeys Hooke's law. Points **A** and **B** are referred to later in the question.



(a) The sketch graph shows how the extension, x, of the spring varies with the force, F, applied to it.



(i) Explain how the graph shows that the spring obeys Hooke's law. [1]

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(ii) Use the graph to show that the elastic potential energy stored in the spring $= \frac{1}{2} kx^2$, where k is the spring constant. [2]

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(b) The spring requires a force of 0.10 N to compress it 1.0 mm.

(i) Calculate the elastic potential energy stored in it when it is compressed by 80 mm. [3]

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(ii) A small car of mass 0.04 kg is placed at point **A**, against the end of the spring, which is then released. Using your answer to *(b)*(i), calculate the speed with which the car leaves the spring. [2]

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(c) The speed of the car at point **B** (after it has completed the loop) is **0.2 m s^{-1} less than its speed at A**. Determine the mean frictional force on the car during its motion from **A** to **B**. [4]

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10.

(a) (i) Define *power.* [1]

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(ii) Show how the unit **W** can be expressed in terms of the SI base units **kg**, **m** and **s**. [2]

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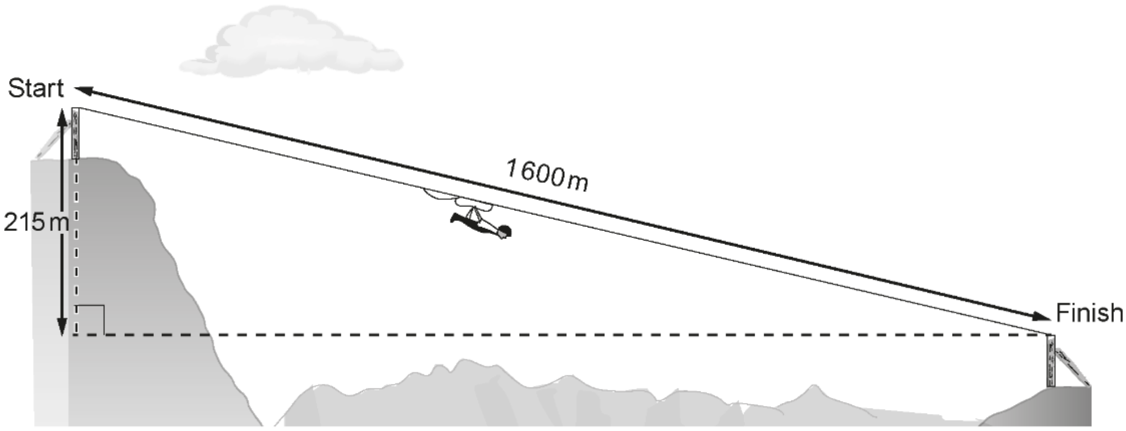
(b) The longest zip-wire ride in the UK is in Snowdonia, North Wales. It is 1600 m long and the vertical drop from start to finish is 215 m as shown. The diagram is not to scale.



(i) A person of mass 70 kg arrives at the finish travelling at 35 m s^{-1}, having started from rest. Use this data and information from the diagram opposite to determine the mean force opposing the motion of the person. [4]

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(ii) The time taken to travel from start to finish is 46 s. Calculate the mean rate at which energy is transferred to the surroundings during the journey. [2]

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