M2: Work, Energy and Power

Past Paper Questions
2006 - 2013

Name:

January 2006

1 A stone, of mass 0.4 kg, is thrown vertically upwards with a speed of $8\,\text{m s}^{-1}$ from a point at a height of 6 metres above ground level.

(a) Calculate the initial kinetic energy of the stone. *(2 marks)*

(b) (i) Show that the kinetic energy of the stone when it hits the ground is 36.3 J, correct to three significant figures. *(2 marks)*

(ii) Hence find the speed at which the stone hits the ground. *(3 marks)*

(iii) State one assumption that you have made. *(1 mark)*

June 2006

2 A ball of mass 0.6 kg is thrown vertically upwards from ground level with an initial speed of $14\,\text{m s}^{-1}$.

(a) Calculate the initial kinetic energy of the ball. *(2 marks)*

(b) Assuming that no resistance forces act on the ball, use an energy method to find the maximum height reached by the ball. *(3 marks)*

(c) An experiment is conducted to confirm the maximum height for the ball calculated in part (b). In this experiment the ball rises to a height of only 8 metres.

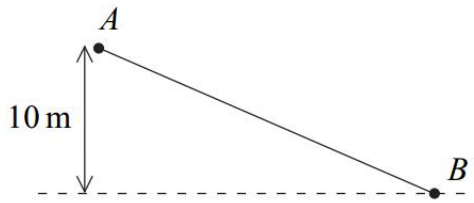
(i) Find the work done against the air resistance force that acts on the ball as it moves. *(3 marks)*

(ii) Assuming that the air resistance force is constant, find its magnitude. *(2 marks)*

(d) Explain why it is **not** realistic to model the air resistance as a constant force. *(1 mark)*

January 2007

1 A child, of mass 35 kg, slides down a slide in a water park. The child, starting from rest, slides from the point A to the point B, which is 10 metres vertically below the level of A, as shown in the diagram.



(a) In a simple model, all resistance forces are ignored.

Use an energy method to find the speed of the child at B. *(3 marks)*

(b) State one resistance force that has been ignored in answering part (a). *(1 mark)*

(c) In fact, when the child slides down the slide, she reaches B with a speed of $12\,\text{m s}^{-1}$.

Given that the slide is 20 metres long and the sum of the resistance forces has a constant magnitude of F newtons, use an energy method to find the value of F.

(4 marks)

7 A motorcycle has a maximum power of 72 kilowatts. The motorcycle and its rider are travelling along a straight horizontal road. When they are moving at a speed of $V\,\text{m s}^{-1}$, they experience a total resistance force of magnitude kV newtons, where k is a constant.

(a) The maximum speed of the motorcycle and its rider is $60\,\text{m s}^{-1}$.

Show that $k = 20$. *(3 marks)*

June 2007

1 A hot air balloon moves vertically upwards with a constant velocity. When the balloon is at a height of 30 metres above ground level, a box of mass 5 kg is released from the balloon.

After the box is released, it initially moves vertically upwards with speed $10\,\text{m s}^{-1}$.

(a) Find the initial kinetic energy of the box. *(2 marks)*

(b) Show that the kinetic energy of the box when it hits the ground is 1720 J. *(3 marks)*

(c) Hence find the speed of the box when it hits the ground. *(3 marks)*

(d) State **two** modelling assumptions which you have made. *(2 marks)*

January 2008

1 A ball is thrown vertically upwards from ground level with an initial speed of $15\,\text{m s}^{-1}$. The ball has a mass of 0.6 kg. Assume that the only force acting on the ball after it is thrown is its weight.

(a) Calculate the initial kinetic energy of the ball. *(2 marks)*

(b) By using conservation of energy, find the maximum height above ground level reached by the ball. *(3 marks)*

(c) By using conservation of energy, find the kinetic energy and the speed of the ball when it is at a height of 3 m above ground level. *(4 marks)*

(d) State one modelling assumption which has been made. *(1 mark)*

June 2008

4 A van, of mass 1500 kg, has a maximum speed of $50\,\text{m s}^{-1}$ on a straight horizontal road. When the van travels at a speed of $v\,\text{m s}^{-1}$, it experiences a resistance force of magnitude $40v$ newtons.

(a) Show that the maximum power of the van is 100 000 watts. *(2 marks)*

(b) The van is travelling along a straight horizontal road.

Find the maximum possible acceleration of the van when its speed is $25\,\text{m s}^{-1}$. *(3 marks)*

(c) The van starts to climb a hill which is inclined at 6° to the horizontal. Find the maximum possible constant speed of the van as it travels in a straight line up the hill. *(6 marks)*

January 2009

2 A stone, of mass 6 kg, is thrown vertically upwards with a speed of $12\,\text{m s}^{-1}$ from a point at a height of 4 metres above ground level.

(a) Calculate the initial kinetic energy of the stone. *(2 marks)*

(b) (i) Show that the kinetic energy of the stone when it hits the ground is 667 J, correct to three significant figures. *(2 marks)*

(ii) Hence find the speed of the stone when it hits the ground. *(3 marks)*

(iii) State two modelling assumptions that you have made. *(2 marks)*

6 A train, of mass 60 tonnes, travels on a straight horizontal track. It has a maximum speed of $40\,\text{m s}^{-1}$ when its engine is working at 800 kW.

(a) Find the magnitude of the resistance force acting on the train when the train is travelling at its maximum speed. *(3 marks)*

(b) When the train is travelling at $40\,\text{m s}^{-1}$, the power is turned off. Assume that the resistance force is constant and is equal to that found in part (a). Also assume that this resistance force is the only horizontal force acting on the train.

Use an energy method to find how far the train travels when slowing from $40\,\text{m s}^{-1}$ to $36\,\text{m s}^{-1}$. *(4 marks)*

June 2009

2 A slide at a water park may be modelled as a smooth plane of length 20 metres inclined at 30° to the vertical. Anne, who has a mass of 55 kg, slides down the slide. At the top of the slide, she has an initial velocity of $3\,\text{m s}^{-1}$ down the slide.

(a) Calculate Anne's initial kinetic energy. *(2 marks)*

(b) By using conservation of energy, find the kinetic energy and the speed of Anne after she has travelled the 20 metres. *(6 marks)*

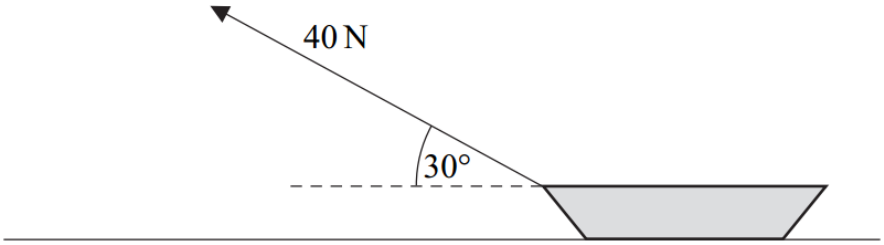
(c) State one modelling assumption which you have made. *(1 mark)*

5 A train, of mass 600 tonnes, travels at constant speed up a slope inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{40}$. The speed of the train is $24\,\text{m s}^{-1}$ and it experiences total resistance forces of 200 000 N.

Find the power produced by the train, giving your answer in kilowatts. *(6 marks)*

January 2010

1 An inextensible rope is attached to a sledge which is at rest on a horizontal surface. A constant force of magnitude 40 newtons at an angle of 30° to the horizontal is applied to the sledge, as shown in the diagram.



Calculate the work done by the force as the sledge is moved 5 metres along the surface.

(3 marks)

June 2010

2 John is at the top of a cliff, looking out over the sea. He throws a rock, of mass 3 kg, horizontally with a velocity of $4\,\text{m}\,\text{s}^{-1}$.

The rock falls a vertical distance of 51 metres to reach the surface of the sea.

(a) Calculate the kinetic energy of the rock when it is thrown. *(2 marks)*

(b) Calculate the potential energy lost by the rock when it reaches the surface of the sea. *(2 marks)*

(c) (i) Find the kinetic energy of the rock when it reaches the surface of the sea.

(ii) Hence find the speed of the rock when it reaches the surface of the sea. *(4 marks)*

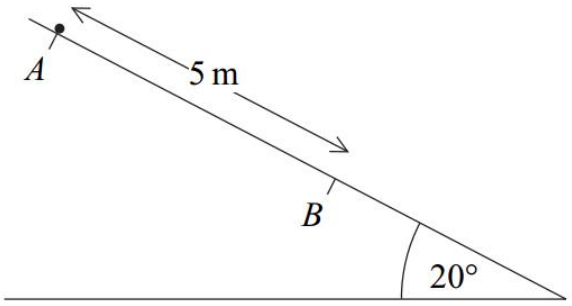
(d) State one modelling assumption which has been made. *(1 mark)*

6 When a car, of mass 1200 kg, travels at a speed of $v\,\text{m}\,\text{s}^{-1}$, it experiences a resistance force of magnitude $30v$ newtons.

The car has a maximum constant speed of $48\,\text{m}\,\text{s}^{-1}$ on a straight horizontal road.

(a) Show that the maximum power of the car is 69 120 watts. *(2 marks)*

2 A particle is placed on a smooth plane which is inclined at an angle of 20° to the horizontal. The particle, of mass 4 kg, is released from rest at a point A and travels down the plane, passing through a point B. The distance AB is 5 m.



(a) Find the potential energy lost as the particle moves from point A to point B. *(2 marks)*

(b) Hence write down the kinetic energy of the particle when it reaches point B. *(1 mark)*

(c) Hence find the speed of the particle when it reaches point B. *(2 marks)*

3 A pump is being used to empty a flooded basement.

In one minute, 400 litres of water are pumped out of the basement.

The water is raised 8 metres and is ejected through a pipe at a speed of $2\,\text{m}\,\text{s}^{-1}$.

The mass of 400 litres of water is 400 kg.

(a) Calculate the gain in potential energy of the 400 litres of water. *(1 mark)*

(b) Calculate the gain in kinetic energy of the 400 litres of water. *(1 mark)*

(c) Hence calculate the power of the pump, giving your answer in watts. *(2 marks)*

June 2011

1 In an Olympic diving competition, Kim, who has mass 58 kg, dives from a fixed platform, 10 metres above the surface of the pool. She leaves the platform with a speed of $2\,\mathrm{m\,s^{-1}}$.

Assume that Kim's weight is the only force that acts on her after she leaves the platform. Kim is to be modelled as a particle which is initially 1 metre above the platform.

(a) Calculate Kim's initial kinetic energy. *(2 marks)*

(b) By using conservation of energy, find Kim's speed when she is 6 metres below the platform. *(5 marks)*

5 A train consists of an engine and five carriages. A constant resistance force of 3000 N acts on the engine, and a constant resistance force of 400 N acts on each of the five carriages.

The maximum speed of the train on a horizontal track is $90\,\mathrm{km\,h^{-1}}$.

(a) Show that this speed is $25\,\mathrm{m\,s^{-1}}$. *(1 mark)*

(b) Hence find the maximum power output of the engine. Give your answer in kilowatts. *(3 marks)*

January 2012

1 A plane is dropping packets of aid as it flies over a flooded village. The speed of a packet when it leaves the plane is $60\,\mathrm{m\,s^{-1}}$. The packet has mass 25 kg.

The packet falls a vertical distance of 34 metres to reach the ground.

(a) Calculate the kinetic energy of the packet when it leaves the plane. *(2 marks)*

(b) Calculate the potential energy lost by the packet as it falls to the ground. *(2 marks)*

(c) Assume that the effect of air resistance on the packet as it falls can be neglected.

(i) Find the kinetic energy of the packet when it reaches the ground. *(2 marks)*

(ii) Hence find the speed of the packet when it reaches the ground. *(2 marks)*

4 A car travels along a straight horizontal road. When its speed is $v\,\mathrm{m\,s^{-1}}$, the car experiences a resistance force of magnitude $25v$ newtons.

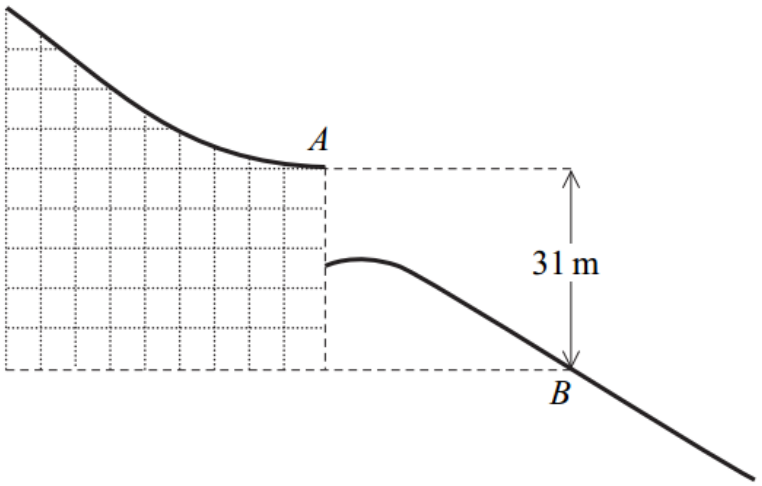
(a) The car has a maximum constant speed of $42\,\mathrm{m\,s^{-1}}$ on this road.

Show that the power being used to propel the car at this speed is 44 100 watts. *(2 marks)*

1 Alan, of mass 76 kg, performed a ski jump. He took off at the point A at the end of the ski run with a speed of $28\,\text{m}\,\text{s}^{-1}$ and landed at the point B.

The level of the point B is 31 metres vertically below the level of the point A, as shown in the diagram.

Assume that his weight is the only force that acted on Alan during the jump.



(a) Calculate the kinetic energy of Alan when he was at the point A. *(2 marks)*

(b) Calculate the potential energy lost by Alan during the jump as he moved from the point A to the point B. *(2 marks)*

(c) (i) Find the kinetic energy of Alan when he reached the point B. *(2 marks)*

(ii) Hence find the speed of Alan when he reached the point B. *(2 marks)*

January 2013

1 Tim is playing cricket. He hits a ball at a point A. The speed of the ball immediately after being hit is $11\,\text{m s}^{-1}$.

The ball strikes a tree at a point B. The height of B is 5 metres above the height of A.

The ball is to be modelled as a particle of mass 0.16 kg being acted upon only by gravity.

(a) Calculate the initial kinetic energy of the ball. *(2 marks)*

(b) Calculate the potential energy gained by the ball as it moves from the point A to the point B. *(2 marks)*

(c) (i) Find the kinetic energy of the ball immediately before it strikes the tree. *(2 marks)*

(ii) Hence find the speed of the ball immediately before it strikes the tree. *(2 marks)*

3 A van, of mass 1500 kg, travels at a constant speed of $22\,\text{m s}^{-1}$ up a slope inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{25}$.

The van experiences a resistance force of 8 000 N.

Find the power output of the van's engine, giving your answer in kilowatts. *(5 marks)*

June 2013

2 Carol, a circus performer, is on a swing. She jumps off the swing and lands in a safety net. When Carol leaves the swing, she has a speed of $7\,\text{m s}^{-1}$ and she is at a height of 8 metres above the safety net.

Carol is to be modelled as a particle of mass 52 kg being acted upon only by gravity.

(a) Find the kinetic energy of Carol when she leaves the swing. *(2 marks)*

(b) Show that the kinetic energy of Carol when she hits the net is 5350 J, correct to three significant figures. *(3 marks)*

(c) Find the speed of Carol when she hits the net. *(3 marks)*

7 A train, of mass 22 tonnes, moves along a straight horizontal track. A constant resistance force of 5000 N acts on the train. The power output of the engine of the train is 240 kW.

Find the acceleration of the train when its speed is $20\,\text{m s}^{-1}$. *(6 marks)*