WORK, ENERGY AND POWER

When necessary take g as 9.8 ms^{-2}

1. A car of mass 900 kg accelerates from rest, attaining a speed of 20 ms^{-1} in 30 seconds. When the car is moving at 15 ms^{-1} the power at which the engine is working is 24 kW. Find the resistive force which is opposing the motion of the car at this instant.

[9]

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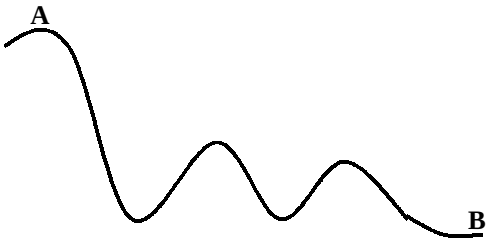
2. A toy car of mass 0.4 kg is released from rest at the point A and travels along a rough track as shown in the diagram.



It comes to rest at the point B. The point A is h m vertically above B and the track is length 4h m. Find the magnitude of the frictional force.

[7]

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3. A car of mass 1200 kg is moving with constant speed v ms^{-1} along a straight level road against a constant resistance of 400 N. The engine of the car is working at a rate of 3 kW.

a) Find v.

[4]

The car accelerates at a constant rate for 1 minute, after which it is moving at 2v ms^{-1}.

b) Find, in kW, the rate at which the engine was working at the instant when the car's speed is 2v.

[8]

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4. A motor scooter and rider of weight 1000N are travelling along a road which is inclined at angle θ, where $\sin\theta = \frac{1}{10}$. The scooter with rider moves up this hill at a steady speed of 30 ms^{-1} against a constant resistive force of 450N with the engine of the scooter working at H kilowatts.

a) Find the value of H

[6]

The scooter and rider move down the same hill at a steady speed of v ms^{-1} against the same constant resistive force with the engine working at H kilowatts.

b) Find the value of v.

[5]

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5. A car of mass 1200 kg is pulling a caravan of mass 500 kg along a level road. For the car there is a constant resistance to motion of 400N and for the caravan the resistance is 200N. If the car and caravan are travelling at a steady speed of 70 kmh^{-1}, find

a) The rate of working of the car's engine

[7]

b) The tension in the horizontal tow bar that connects the caravan to the car

[3]

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6. The only forces acting on a particle of mass 2 kg are gravity and friction

a) When the particle is projected with a speed of 5 ms^{-1} along a rough horizontal plane it travels a distance of 1.5 m before coming to rest. Use energy consideration to show that the coefficient of friction is 0.85 correct to two significant figures.

[8]

b) The plane is tilted upwards so that it makes an angle of 30^o with the horizontal. Find the initial speed of projection required if the particle again travels 1.5 m up the plane before coming to rest.

[9]

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7. A box of mass 10 kg is being pulled at a steady speed along a rough horizontal plane by a rope that makes an angle of 30^o with the horizontal. The coefficient of friction between the box and the ground is 0.4. Find the work done against friction when the box is pulled 8 m along the plane.

[10]

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8. At the post office parcels are sent down a chute into a large bag. The chute is 1.5 m long and makes an angle of 30^o with the vertical. A particle of mass 3 kg is placed at the top of the chute and has a speed of 0.4 ms^{-1} when it falls into the bag.

a) Find, by energy considerations, the frictional force on the parcel while it is sliding down the chute.

[9]

b) State two assumptions you have made in your solution

[2]

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9. The seat of a child's swing is h above the ground. George, whose mass is m, propels himself to a height of 4h above the ground. His speed is u at the instant when he is 4h above the ground.

a) Find the work done by George, giving your answer in terms of m, u, g and h.

[4]

George is given a 'push' by his father so that his initial speed is $\frac{1}{2}$ u ms^{-1}.

b) Find how much less work he now has to do to achieve a height of 4 m and speed of u ms^{-1}.

[4]

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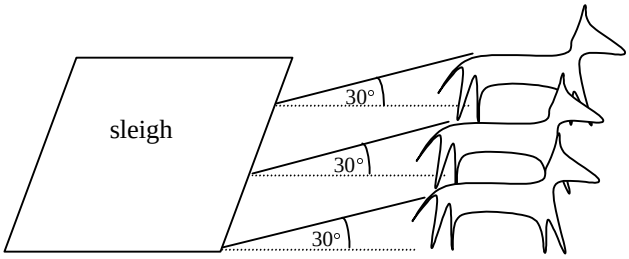
10. A team of 3 husky dogs each of weight W newtons is pulling a sleigh of weight 5W newtons across a rough ice-covered horizontal plane. The ropes that attach each dog to the sleigh make angles of 30^o with the horizontal. The coefficient of friction between the sleigh and the ice is 0.1 and between a dog and the ice is 0.2.



Assuming that there are no other resistive forces, find in terms of W, the rate at which each dog is working when the sleigh is moving at a steady speed of 2 ms^{-1}.

[12]

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11. A pump, working at its maximum power, is pumping up water from a well that is 7 metres deep. It pumps up 3 x 10^6 cm^3 of water per minute and the water gushes from the well with a speed of 10 ms^{-1}. Find the maximum effective power of the pump, giving your answer in kW.

[10]

(1cm^3 of water weighs 1 gramme)

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12. Alice is picking up pebbles from the beach and throwing them into the sea. She throws them from a height of 1.5 m. When she throws a pebble of mass 0.4 kg, its velocity as it leaves her hand is 10 ms^{-1}.

a) Find how much work Alice does in throwing the pebble.

[6]

b) If she expends the same energy in throwing a pebble of 0.2 kg find the initial speed of that pebble.

[4]

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13.An engine of mass 40 tonnes is pulling eight identical coaches each of mass 2 tonnes along a horizontal railway track. The frictional resistance to the motion of both the engine and the trucks is constant and is of magnitude 40N per tonne mass.

a) Find, in kW, the power of the engine when the train is moving at a steady speed of 50 ms^{-1}.

[7]

The train begins to travel down a slope of 400 m inclined at an angle of θ where $\sin\theta = \frac{1}{20}$.

The tractive force of the engine is unchanged.

b) Find

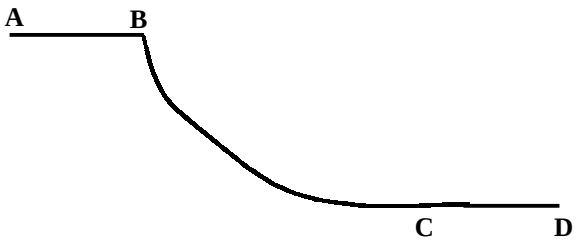
i) the acceleration of the train down the slope

[4]

ii) the power of the engine, in kW, when the train is at the bottom of the slope.

[4]

14.



The diagram shows a playground slide. The section BC is 3 m long and the horizontal section CD is 1.5 m long. The platform AB is 2 m vertically above CD. Sonal, whose mass is 25 kg, starts from rest at B, and having come down the slide she comes to rest on the section CD, 0.5 m from D.

a) Find the constant resistive force to the motion

[7]

b) When she goes on the slide again Sonal propels herself from B with speed u ms^{-1}.
Find the maximum value of u, given that Sonal will stop on reaching the end of the slide.

[6]

c) State two assumptions you have made in your solutions

[2]

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15. A car of mass 1000 kg is towing a caravan of mass 700 kg along a level road at a steady speed of 90 kmh^{-1}. There is a constant frictional resistance to motion of 100 N on the car and 150 N on the caravan.

a) Find the tension in the tow-bar.

[4]

b) Show that the engine is working at 6.25 kW.

[6]

The car and caravan start to go down a hill that makes an angle of 10^o with the horizontal. The power of the engine is kept constant at 6.25 kW.

c) Find the acceleration of the car and caravan at the instant when it is descending the hill with speed 126 kmh^{-1}.

[4]

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16. A car whose weight is 9000 N can maintain a steady speed of 40 ms^{-1} on level ground when the engine is working at a rate of 60 kW. At all times the resistance to motion is given by kv^2 newtons, where v ms^{-1} is the speed of the car and k is a constant.

a) Find the value of k.

[5]

The car is travelling up a hill which makes an angle θ the horizontal, where $\sin\theta = \frac{1}{5}$.
The engine is working at a rate of 80 kW.

b) Find the acceleration of the car when it is travelling at a speed of 20 ms^{-1}.

[9]

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17. A cyclist and her bicycle have a total mass of M kg. When cycling up a hill of angle of inclination θ to the horizontal her maximum speed is u ms^{-1} and when travelling down the same hill it is 2u ms^{-1}. She is working at her maximum rate when going both up and down the hill, and there is a constant resistance R to her motion.

a) Find, in terms of M, g, u and θ, an expression for the power she develops

[10]

b) Find an expression for her maximum speed on level ground.

[4]

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18. A battery operated robot moves along a track where the frictional resistances are proportional to the speed of the car. The track is as shown in the diagram below.

The sections AB and CD are both at angle θ to the horizontal, where $\sin\theta = \frac{1}{5}$. BC is horizontal.

The battery always works at a rate of 5kW and the robot has weight 500N.

Given that the robot has a maximum speed of $10ms^{-1}$ when it is moving up AB, find its maximum speed

a) on the horizontal section BC

[11]

b) when it is moving down the section CD

[5]

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19. The frictional resistive forces opposing the motion of a car of mass 1500 kg are constant and of magnitude 2000 N. The car is accelerating at a rate of $1.5\ ms^{-2}$ while travelling on a level road at $12\ ms^{-1}$. Find the power, in kW, with which the engine is working.

[7]

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20. The surface of a road is such that the frictional resistive forces to motion of any vehicle travelling on it are proportional to the weight of the vehicle. When a car of mass 1200 kg is towing an empty trailer of mass 200 kg the total resistive forces are 2100 N.

a) The maximum power of the car's engine is 65 kW. Find the maximum speed the car can reach on a horizontal stretch of road.

[5]

b) A load of mass 400 kg is put in the trailer. Find the maximum speed that the car and the trailer could reach when travelling up a slope inclined at angle θ , where $\sin\theta = \frac{1}{15}$.

[8]

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21. A plane of mass 70 tonnes is cruising at a steady speed of 200 ms^{-1}. It is flying horizontally and each of its four engines produce a thrust of 15×10^4 N.

a) Find the total resistance to the motion

[4]

b) Find the total power of the engines

[2]

The resistance to motion is proportional to the speed of the plane, and the power of the engines remains constant.

c) Find in ms^{-2} the acceleration of the plane when it is climbing at an angle of 30^o to the horizontal and travelling at a speed of 150 ms^{-1}.

[10]

22.A train of mass M moves with acceleration a, along a straight level track against a constant resistance of magnitude R. Find the rate at which the engine of the train is working when the speed is v, giving your answer in terms of v, R, M and a.

[4]

23.A particle of mass 0.3 kg is moving with velocity $(2\mathbf{i} - 4\mathbf{j})$ ms^{-1} in a horizontal plane. Find

a) the magnitude of the momentum of the particle

[3]

b) the kinetic energy of the particle.

[3]

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24. Two particles A and B of masses 0.3 kg and 0.4 kg respectively are connected by a light inelastic string passing over a fixed light smooth pulley. The particles are released from rest with the string taut and the hanging parts vertical. Find the kinetic energy of the system after it has been in motion for 1.5s.

[9]
