Work, energy and power – 2023 AS Mathematics 9709

1. Nov/2023/Paper_9709/41/No.1

A particle of mass $1.6\,\text{kg}$ is projected with a speed of $20\,\text{m s}^{-1}$ 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]

A car of mass $1300\,\text{kg}$ is moving on a straight road.

(a) On a horizontal section of the road, the car has a constant speed of $30\,\text{m s}^{-1}$ and there is a constant force of $650\,\text{N}$ resisting the motion.

(i) Calculate, in kW, the power developed by the engine of the car. [2]

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(ii) Given that this power is suddenly increased **by** $9\,\text{kW}$, find the instantaneous acceleration of the car. [3]

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(b) On a section of the road inclined at $\sin^{-1} 0.08$ to the horizontal, the resistance to the motion of the car is $(1000 + 20v)\,\text{N}$ when the speed of the car is $v\,\text{m s}^{-1}$. The car travels downwards along this section of the road at constant speed with the engine working at $11.5\,\text{kW}$.
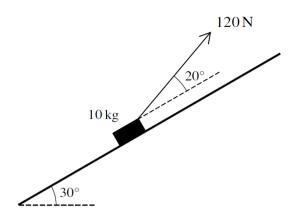
Find this constant speed. [4]

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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 $2\,\text{m s}^{-1}$ and the speed of the block at the bottom of the plane is $4\,\text{m s}^{-1}$.

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

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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A car has mass $1600\,\text{kg}$.

(a) The car is moving along a straight horizontal road at a constant speed of $24\,\text{m s}^{-1}$ and is subject to a constant resistance of magnitude $480\,\text{N}$.

Find, in kW, the rate at which the engine of the car is working. [2]

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The car now moves down a hill inclined at an angle of θ to the horizontal, where $\sin\theta = 0.09$. The engine of the car is working at a constant rate of $12\,\text{kW}$. The speed of the car is $24\,\text{m s}^{-1}$ at the top of the hill. Ten seconds later the car has travelled $280\,\text{m}$ down the hill and has speed $32\,\text{m s}^{-1}$.

(b) Given that the resistance is not constant, use an energy method to find the total work done against the resistance during the ten seconds. [5]

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A crate of mass 200 kg is being pulled at constant speed along horizontal ground by a horizontal rope attached to a winch. The winch is working at a constant rate of 4.5 kW and there is a constant resistance to the motion of the crate of magnitude 600 N.

(a) Find the time that it takes for the crate to move a distance of 15 m. [2]

The rope breaks after the crate has moved 15 m.

(b) Find the time taken, after the rope breaks, for the crate to come to rest. [3]