A Level · Edexcel · Further Maths

2 hours 12 questions

Work, Energy & Power

Work Done / Kinetic & Potential Energy / Work-Energy Principle / Problem Solving with Energy / Power

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Total Marks **/110**

1 (a) A parcel of mass 5 kg is projected with speed 8 ms^{-1} up a line of greatest slope of a fixed rough inclined ramp.

The ramp is inclined at angle α to the horizontal, where $\sin\alpha = \frac{1}{7}$.

The parcel is projected from the point A on the ramp and comes to instantaneous rest at the point B on the ramp, where AB = 14 m.

The coefficient of friction between the parcel and the ramp is μ.

In a model of the parcel's motion, the parcel is treated as a particle.

Use the work-energy principle to find the value of μ.

(5 marks)

(b) Suggest one way in which the model could be refined to make it more realistic.

(1 mark)

2 (a) A car of mass 600 kg is moving along a straight horizontal road.

At the instant when the speed of the car is $v\ \mathrm{ms}^{-1}$, the resistance to the motion of the car is modelled as a force of magnitude $(200 + 2v)$ N.

The engine of the car is working at a constant rate of 12 kW.

Find the acceleration of the car at the instant when $v = 20$.

(4 marks)

(b) Later on the car is moving up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \dfrac{1}{14}$.

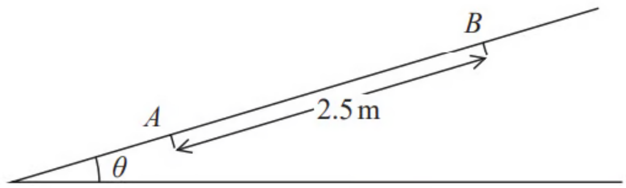
At the instant when the speed of the car is $v\ \mathrm{ms}^{-1}$, the resistance to the motion of the car from non-gravitational forces is modelled as a force of magnitude $(200 + 2v)$ N.

The engine is again working at a constant rate of 12 kW.

At the instant when the car has speed $w\ \mathrm{ms}^{-1}$, the car is decelerating at 0.05 ms^{-2}.

Find the value of w.

(5 marks)



3 (a) **Figure 1**

Figure 1 shows a ramp inclined at an angle θ to the horizontal, where $\sin\theta = \frac{2}{7}$

A parcel of mass 4 kg is projected, with speed 5 ms^{-1}, from a point A on the ramp. The parcel moves up a line of greatest slope of the ramp and first comes to instantaneous rest at the point B, where AB = 2.5 m.
The parcel is modelled as a particle.

The total resistance to the motion of the parcel from non-gravitational forces is modelled as a constant force of magnitude R newtons.

Use the work-energy principle to show that R = 8.8 .

(4 marks)

(b) After coming to instantaneous rest at B, the parcel slides back down the ramp. The total resistance to the motion of the particle is modelled as a constant force of magnitude 8.8 N.

Find the speed of the parcel at the instant it returns to A.

(3 marks)

(c) Suggest two improvements that could be made to the model.

(2 marks)

4 (a) A van of mass 750 kg is moving along a straight horizontal road. At the instant when the van is moving at $v \text{ ms}^{-1}$, the resistance to the motion of the van is modelled as a force of magnitude λv N, where λ is a constant.

The engine of the van is working at a constant rate of 18 kW.
At the instant when $v = 15$, the acceleration of the van is 0.6 ms^{-2}.

Show that $\lambda = 50$.

(4 marks)

(b) The van now moves up a straight road inclined at an angle to the horizontal, where
$\sin \alpha = \dfrac{1}{15}$
At the instant when the van is moving at $v \text{ ms}^{-1}$, the resistance to the motion of the van from non-gravitational forces is modelled as a force of magnitude $50v$ N.
When the engine of the van is working at a constant rate of 12 kW, the van is moving at a constant speed $V \text{ ms}^{-1}$.

Find the value of V.

(5 marks)

5 (a) A lorry of mass 16 000 kg moves along a straight horizontal road.

The lorry moves at a constant speed of 25 ms^{-1}

In an initial model for the motion of the lorry, the resistance to the motion of the lorry is modelled as having constant magnitude 16 000 N.

Show that the engine of the lorry is working at a rate of 400 kW.

(4 marks)

(b) The model for the motion of the lorry along the same road is now refined so that when the speed of the lorry along the same road is V ms^{-1}, the resistance to the motion of the lorry is modelled as having magnitude $640V$ Newtons.

Assuming that the engine of the lorry is working at the same rate of 400 kW,

use the refined model to find the speed of the lorry when it is accelerating at 2.1 ms^{-2}.

(6 marks)

6 A particle, P, of mass m kg is projected with speed 5 ms^{-1} down a line of greatest slope of a rough plane. The plane is inclined to the horizontal at an angle α, where $\sin \alpha = \frac{3}{5}$.

The total resistance to the motion of P is a force of magnitude $\frac{1}{5}mg$.

Use the work-energy principle to find the speed of P at the instant when it has moved a distance 8 m down the plane from the point of projection.

(7 marks)

7 (a) A car of mass 600 kg pulls a trailer of mass 150 kg along a straight horizontal road. The trailer is connected to the car by a light inextensible towbar, which is parallel to the direction of motion of the car. The resistance to the motion of the trailer is modelled as a constant force of magnitude 200 N. At the instant when the speed of the car is v ms^{-1}, the resistance to the motion of the car is modelled as a force of magnitude $(200 + \lambda v)$ N, where λ is a constant.

When the engine of the car is working at a constant rate of 15 kW, the car is moving at a constant speed of 25 ms^{-1}.

Show that $\lambda = 8$.

(4 marks)

(b) Later on, the car is pulling the trailer up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{15}$.

The resistance to the motion of the trailer from non-gravitational forces is modelled as a constant force of magnitude 200 N at all times. At the instant when the speed of the car is v ms^{-1}, the resistance to the motion of the car from non-gravitational forces is modelled as a force of magnitude $(200 + 8v)$ N.

The engine of the car is again working at a constant rate of 15 kW.

When $v = 10$, the towbar breaks. The trailer comes to instantaneous rest after moving a distance d metres up the road from the point where the towbar broke.

Find the acceleration of the car immediately after the towbar breaks.

(4 marks)

(c) Use the work-energy principle to find the value of d.

(4 marks)

8 (a) A car of mass 1000 kg moves along a straight horizontal road.

In all circumstances, when the speed of the car is $v\ \mathrm{ms}^{-1}$, the resistance to the motion of the car is modelled as a force of magnitude $cv^2\ \mathrm{N}$, where c is a constant.

The maximum power that can be developed by the engine of the car is 50 kW.

At the instant when the speed of the car is 72 kmh^{-1} and the engine is working at its maximum power, the acceleration of the car is 2.25 ms^{-2}.

Convert 72 kmh^{-1} into ms^{-1}.

(1 mark)

(b) Find the acceleration of the car at the instant when the speed of the car is 144 kmh^{-1} and the engine is working at its maximum power.

(7 marks)

(c) The maximum speed of the car when the engine is working at its maximum power is V kmh^{-1}.

Find, to the nearest whole number, the value of V.

(4 marks)

9 (a) A truck of mass 1200 kg is moving along a straight horizontal road.

At the instant when the speed of the truck is $v$ms^{-1}, the resistance to the motion of the truck is modelled as a force of magnitude $(900+9v)$ N.

The engine of the truck is working at a constant rate of 25 kW.

Find the deceleration of the truck at the instant when $v=25$.

(4 marks)

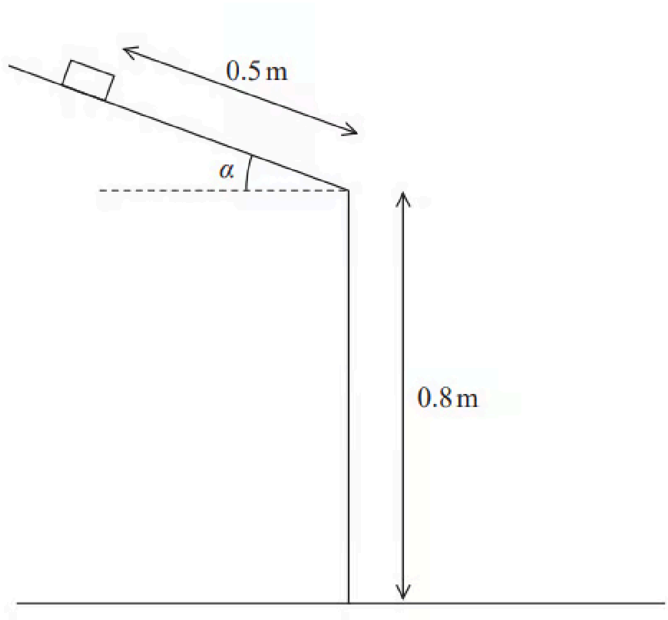
(b) Later on, the truck is moving up a straight road that is inclined at an angle θ to the horizontal, where $\sin\theta = \dfrac{1}{20}$.

At the instant when the speed of the truck is v ms^{-1}, the resistance to the motion of the truck from non-gravitational forces is modelled as a force of magnitude $(900+9v)$ N.

When the engine of the truck is working at a constant rate of 25 kW the truck is moving up the road at a constant speed of V ms^{-1}.

Find the value of V.

(5 marks)



10 (a) **Figure 1**

A small book of mass m is held on a rough straight desk lid which is inclined at an angle α to the horizontal, where $\tan \alpha = \frac{3}{4}$.

The book is released from rest at a distance of 0.5 m from the edge of the desk lid, as shown in Figure 1. The book slides down the desk lid and then hits the floor that is 0.8 m below the edge of the desk lid. The coefficient of friction between the book and the desk lid is 0.4.

The book is modelled as a particle which, after leaving the desk lid, is assumed to move freely under gravity.

Find, in terms of m and g, the magnitude of the normal reaction on the book as it slides down the desk lid.

(2 marks)

(b) Use the work-energy principle to find the speed of the book as it hits the floor.

(5 marks)

11 (a) The total mass of a cyclist and his bicycle is 100 kg.

In all circumstances, the magnitude of the resistance to the motion of the cyclist from non-gravitational forces is modelled as being kv^2 N, where v ms^{-1} is the speed of the cyclist.

The cyclist can freewheel, without pedalling, down a slope that is inclined to the horizontal at an angle α, where $\sin\alpha = \frac{1}{35}$, at a constant speed of V ms^{-1}.

When he is pedalling up a slope that is inclined to the horizontal at an angle β, where $\sin\beta = \frac{1}{70}$, and he is moving at the same constant speed V ms^{-1}, he is working at a constant rate of P watts.

Find P in terms of V.

(7 marks)

(b) If he pedals and works at a rate of $35V$ Watts on a horizontal road, he moves at a constant speed of U ms^{-1}.

Find U in terms of V.

(4 marks)

12 (a) A van of mass 900 kg is moving along a straight horizontal road.

At the instant when the speed of the van is v ms^{-1}, the resistance to the motion of the van is modelled as a force of magnitude $(500 + 7v)$ N.

When the engine of the van is working at a constant rate of 18 kW, the van is moving along the road at a constant speed V ms^{-1}.

Find the value of V.

(5 marks)

(b) Later on, the van is moving up a straight road that is inclined to the horizontal at an angle θ, where $\sin\theta = \dfrac{1}{21}$.

At the instant when the speed of the van is v ms^{-1}, the resistance to the motion of the van from non-gravitational forces is modelled as a force of magnitude $(500 + 7v)$ N.

The engine of the van is again working at a constant rate of 18 kW.

Find the acceleration of the van at the instant when $v = 15$.

(4 marks)