Power, driving force and maximum speed

92 marks

Hints online, answers free with an account: mathswariz.uk/worksheets/ocr-further-maths-mech-power/

Date

A Do Now

Quick questions to start.

A1 Lesson 1 [2 marks]

A crate is pulled $12\ \text{m}$ along a level floor by a horizontal force of $45\ \text{N}$. Find the work done by the force.

Answer .....

A2 From A-Level Maths [2 marks]

A $1500\ \text{kg}$ car accelerates at $0.8\ \text{m s}^{-2}$ along a level road against a resistance of $600\ \text{N}$. Find the driving force.

Answer .....

A3 From A-Level Maths [2 marks]

Write $24\ \text{kW}$ in watts and $72\ \text{km h}^{-1}$ in metres per second.

Answer .....

A4 Lesson 3 [2 marks]

A cyclist and bicycle of total mass $70\ \text{kg}$ ride up a road that rises $15\ \text{m}$. Find the gain in potential energy.

Answer .....

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Your teacher works each example with you (I do). You try the one beside it together (We do). Then practise that part on your own (You do).

PART 1 Driving force, acceleration and top speed

EXAMPLE 1 · I DO

A car of mass $1200\ \text{kg}$ moves along a level road against a resistance of $500\ \text{N}$. Its engine works at $18\ \text{kW}$. Find its acceleration when its speed is $15\ \text{m s}^{-1}$.

Hint The driving force is $D = P \div v$, using the driving force alone. Do not divide by $D - R$, and do not multiply P by v. Then use $D - R = ma$.

YOUR TURN · WE DO

B1 A van of mass $2500\ \text{kg}$ moves along a level road against a resistance of $900\ \text{N}$. Its engine works at $30\ \text{kW}$. (i) Find its acceleration when its speed is $12\ \text{m s}^{-1}$. (ii) Find its speed when its acceleration is $0.2\ \text{m s}^{-2}$. [5 marks]

Answer .....

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EXAMPLE 2 · I DO

A cyclist can work at $300\ \mathrm{W}$. The resistance to her motion is $24\ \mathrm{N}$. Find her greatest speed on a level road.

Hint At the greatest speed the acceleration is zero, so the driving force equals the resistance. Say so in your answer.

YOUR TURN · WE DO

B2 A car of mass $1100\ \mathrm{kg}$ has a greatest speed of $40\ \mathrm{m\,s^{-1}}$ on a level road when its engine works at its maximum power of $32\ \mathrm{kW}$. The resistance is constant. (i) Find the resistance. (ii) Find the acceleration when the car moves at $25\ \mathrm{m\,s^{-1}}$ with the engine at maximum power. [5 marks]

Answer .....

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C1 A car of mass $900\ \text{kg}$ moves along a level road at $20\ \text{m s}^{-1}$ with its engine working at $12\ \text{kW}$. The resistance is $400\ \text{N}$. Sam writes: [4 marks]

$$D = \frac{12\,000}{20} = 600, \text{ so } a = \frac{600}{900} = 0.667\ \text{m s}^{-2}.$$

Explain Sam's mistake and find the acceleration.

Answer .....

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C2 A car of mass $1000\ \text{kg}$ speeds up from rest to $18\ \text{m s}^{-1}$ in $12\ \text{s}$ along a level road, travelling $120\ \text{m}$. The resistance is $300\ \text{N}$ throughout. (i) Find the average power of the engine over the $12\ \text{s}$. (ii) Explain why this is not the power of the engine at the moment it reaches $18\ \text{m s}^{-1}$. [5 marks]

Answer .....

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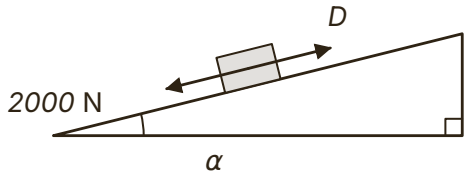
PART 2 Hills and towing a trailer

EXAMPLE 3 · I DO

A lorry of mass $8000\ \text{kg}$ climbs a hill inclined at α, where $\sin\alpha = \frac{1}{25}$, at a constant speed of $12\ \text{m s}^{-1}$. The resistance is $2000\ \text{N}$. Find the power of the engine.



Hint Constant speed, so the forces along the slope balance. Going up, the weight component $mg\sin\alpha$ acts down the slope with the resistance.

YOUR TURN · WE DO

B3 A car of mass $1300\ \text{kg}$ is on a hill inclined at θ, where $\sin\theta = \frac{1}{30}$. The engine works at $15\ \text{kW}$ and the resistance is $950\ \text{N}$. (i) Find the greatest speed of the car DOWN the hill. (ii) Find the greatest speed UP the hill. [5 marks]

Answer .....

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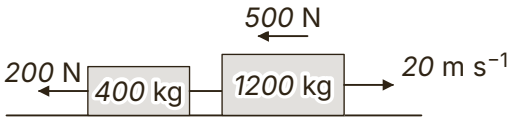
EXAMPLE 4 · I DO

A car of mass $1200\ \text{kg}$ tows a trailer of mass $400\ \text{kg}$ along a level road. The resistances are $500\ \text{N}$ on the car and $200\ \text{N}$ on the trailer. The engine works at $24\ \text{kW}$. Find the acceleration and the tension in the tow bar when the speed is $20\ \text{m s}^{-1}$.



Hint Use the whole system for the acceleration: both masses, both resistances. Then use the trailer alone for the tension: the tension pulls it against its own resistance.

YOUR TURN · WE DO

B4 [6 marks]

A tractor of mass $3000\ \text{kg}$ tows a trailer of mass $1500\ \text{kg}$ up a road inclined at α, where $\sin\alpha = \frac{1}{40}$. The resistances are $800\ \text{N}$ on the tractor and $400\ \text{N}$ on the trailer. At $6\ \text{m s}^{-1}$ the engine works at $18\ \text{kW}$. Find the acceleration and the tension in the tow bar.

Answer .....

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C3 A cyclist and bicycle of total mass $80\ \text{kg}$ can work at $0.4\ \text{kW}$. Her greatest speed up a hill inclined at α, where $\sin\alpha = \frac{1}{15}$, is $6\ \text{m s}^{-1}$. Find the resistance, assumed constant. [4 marks]

Answer .....

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C4 A car of mass $1300\ \text{kg}$ tows a caravan of mass $900\ \text{kg}$ up a road inclined at α, where $\sin\alpha = 0.05$. The resistances are $600\ \text{N}$ on the car and $400\ \text{N}$ on the caravan. At an instant when the speed is $18\ \text{m s}^{-1}$ the acceleration is $0.3\ \text{m s}^{-2}$. Find the power of the engine at this instant and the tension in the tow bar. [6 marks]

Answer .....

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PART 3 A resistance that grows with speed

EXAMPLE 5 · I DO

A car of mass $1000\ \text{kg}$ moves on a level road against a resistance of $kv\ \text{N}$, where v is its speed. Working at $20\ \text{kW}$, its greatest speed is $40\ \text{m s}^{-1}$. Find k, then the acceleration when the car moves at $25\ \text{m s}^{-1}$ with the engine still at $20\ \text{kW}$.

Hint At $40\ \text{m s}^{-1}$ the resistance is $40k$, and at $25\ \text{m s}^{-1}$ it is $25k$. The resistance is different at each speed.

YOUR TURN · WE DO

B5 A boat of mass $600\ \text{kg}$ moves against a resistance of $kv\ \text{N}$. With the engine at $9\ \text{kW}$ its greatest speed is $15\ \text{m s}^{-1}$. (i) Find k. (ii) The power is raised to $12\ \text{kW}$. Find the new greatest speed. [5 marks]

Answer .....

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C5 A car of mass $800\ \text{kg}$ moves on a level road. Its engine works at $16\ \text{kW}$ and the resistance is $20v\ \text{N}$, where v is its speed. Find the speed at which its acceleration is $0.5\ \text{m s}^{-2}$, and give the reason for the root you choose. [5 marks]

Answer .....

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C6 A rowing boat and rower have total mass $180\ \text{kg}$. The rower is modelled as working at a constant $300\ \text{W}$ against a resistance of $30v\ \text{N}$. (i) Find the top speed the model predicts. (ii) In a race the boat's top speed was $2.6\ \text{m s}^{-1}$. Comment on the model. (iii) Give one reason why a constant power is not a good model for a rower. [5 marks]

Answer .....

D Exam-style questions

OCR exam style

D1 A car of mass $1400\ \text{kg}$ has a maximum power of $45\ \text{kW}$. On a level road its greatest speed is $50\ \text{m s}^{-1}$. The resistance is constant.

(a) Show that the resistance is $900\ \text{N}$. [2 marks]

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(b) Hence find the acceleration of the car when it moves along the level road at $30\ \mathrm{m\,s^{-1}}$ with the engine at maximum power. [2 marks]

Answer .....

(c) The car climbs a hill inclined at α, where $\sin\alpha = \frac{1}{14}$, with the same resistance. Find its greatest speed up the hill. [3 marks]

Answer .....

(d) Explain why the car cannot move DOWN this hill at a constant speed with its engine working. [3 marks]

Total for D1: 10 marks

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D2

> Alex says: "If the power is halved to $30\ \text{kW}$, the greatest speed on the level road halves too, to $12.5\ \text{m s}^{-1}$."

A lorry of mass $5000\ \text{kg}$ moves against a resistance of $kv\ \text{N}$, where v is its speed. With the engine working at $60\ \text{kW}$, its greatest speed on a level road is $25\ \text{m s}^{-1}$.

(a) Show that $k = 96$. [2 marks]

(b) Hence find the acceleration of the lorry on the level road at $15\ \text{m s}^{-1}$ with the engine at $60\ \text{kW}$. [2 marks]

Answer .....

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(c) Show that Alex is wrong, and find the greatest speed on the level road when the power is $30\ \mathrm{kW}$. [3 marks]

Answer .....

(d) The lorry climbs a hill inclined at α, where $\sin\alpha = \frac{1}{20}$, with the engine at $60\ \mathrm{kW}$. Find its greatest speed, giving the reason for the root you choose. [3 marks]

Answer .....

Total for D2: 10 marks

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E Extension

Stretch

No route is given. The hints are at the end of the sheet. Use one at a time.

E1 [9 marks]

A cyclist and bicycle have total mass $80\ \text{kg}$. She works at a constant $240\ \text{W}$ against a resistance of $kv\ \text{N}$. Her greatest speed on a level road is $10\ \text{m s}^{-1}$. (a) Find k. (b) Find her greatest speed up a hill inclined at α, where $\sin\alpha = \frac{1}{40}$, and her greatest speed down the same hill. (c) Show that, whatever constant power she works at, her greatest speed down the hill is greater than her greatest speed up the hill by $\dfrac{mg\sin\alpha}{k}$, and find this amount.

Answer .....

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Extension hints

Cover these with paper. Uncover one at a time.

E1

Hint 1 At each greatest speed the acceleration is zero, so the driving force P/v balances everything acting against the motion. Multiply every term by v.

Hint 2 Up the hill $mg\sin\alpha$ acts against her; down the hill it acts with her. Write the two quadratics with $W = mg\sin\alpha$.

Hint 3 Put $v = -u$ into the uphill quadratic. You get the downhill quadratic, so $-v_1$ and v_2 are its two roots. Use the sum of the roots.

How did it go?

Colour one circle on each line: not yet, nearly, yes.

I can use $P = Dv$ with Newton's second law to find an acceleration, a resistance or a top speed.	○ ○ ○
I can find a top speed up or down a slope, putting the weight component on the right side.	○ ○ ○
I can solve problems with a car and trailer, or with a resistance kv.	○ ○ ○
I can tell average power from power at an instant and judge a model.	○ ○ ○

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