Work done by a constant force

88 marks

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

Date

A Do Now

Quick questions to start.

A1 From A-Level Maths [2 marks]

A force of $50\ \mathrm{N}$ acts at 30° above the horizontal. Find its horizontal and vertical components.

Answer .....

A2 From A-Level Maths [2 marks]

A crate starts from rest and accelerates at $0.8\ \mathrm{m\,s^{-2}}$. How far does it move in 5 seconds?

Answer .....

A3 From A-Level Maths [2 marks]

A $12\ \mathrm{kg}$ box is pulled along a floor by a horizontal force of $60\ \mathrm{N}$. A resistance of $24\ \mathrm{N}$ acts. Find its acceleration.

Answer .....

A4 From chapter 1 [2 marks]

Force has dimensions MLT^{-2}. Find the dimensions of force $\times$ distance.

Answer .....

B Examples and practice

A-Level Further

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).

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PART 1 Work done along the motion and at an angle

EXAMPLE 1 · I DO

A man pushes a box $6\ \text{m}$ along a floor with a horizontal force of $40\ \text{N}$. He then lifts a $5\ \text{kg}$ parcel $1.2\ \text{m}$ vertically at constant speed. Find the work done by him each time.

Hint Work done = force × distance moved in the direction of the force. At constant speed the lifting force equals the weight.

YOUR TURN · WE DO

B1 (i) A rope with tension $180\ \text{N}$, parallel to the ground, pulls a sledge $25\ \text{m}$. Find the work done by the tension in kJ. (ii) A crane lifts a $350\ \text{kg}$ load $12\ \text{m}$ vertically at constant speed. Find the work done by the crane. [4 marks]

Answer .....

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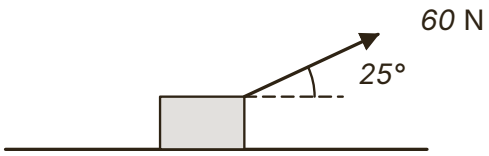
EXAMPLE 2 · I DO

A box is pulled $8\ \text{m}$ across a horizontal floor by a rope at $25°$ above the horizontal. The tension is $60\ \text{N}$. Find the work done by the tension.



Hint Only the part of the force along the motion does work. Resolve the tension along the floor first.

YOUR TURN · WE DO

B2 (i) A lawnmower is pushed $30\ \text{m}$ across level ground by a force of $75\ \text{N}$ along its handle. The handle makes $40°$ with the horizontal. Find the work done by the force. (ii) A rope pulls a cart $15\ \text{m}$ along a level road. The rope makes $62°$ with the vertical and its tension is $40\ \text{N}$. Find the work done by the tension. [4 marks]

Answer .....

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C1 A force of $30\ \mathrm{N}$ acts at 35° to the horizontal on a box. The box moves $12\ \mathrm{m}$ along a horizontal floor. Sam writes: [4 marks]

$$W = 30 \times \sin 35^\circ \times 12 = 206\ \mathrm{J}.$$

Explain Sam's mistake, and find the work done by the force.

Answer .....

C2 A sledge is pulled $40\ \mathrm{m}$ across level snow by a rope with tension $90\ \mathrm{N}$. The work done by the tension is $3200\ \mathrm{J}$. Find the angle between the rope and the horizontal. [4 marks]

Answer .....

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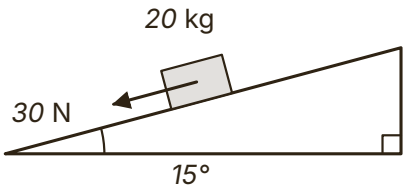
PART 2 Work done on a slope

EXAMPLE 3 · I DO

A $20\ \text{kg}$ crate is pulled $6\ \text{m}$ up a rough slope inclined at 15° to the horizontal. A frictional force of $30\ \text{N}$ acts. Find the work done against gravity and the work done against friction.



Hint The crate rises $6\sin 15^\circ$ metres. Friction acts along the slope, so it is friction × distance along the slope.

YOUR TURN · WE DO

B3 A $45\ \text{kg}$ trolley is pushed $12\ \text{m}$ up a ramp inclined at 8° to the horizontal. A resistance of $40\ \text{N}$ acts along the ramp. Find the total work done against gravity and the resistance. [4 marks]

Answer .....

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EXAMPLE 4 · I DO

A $4\ \text{kg}$ block slides $5\ \text{m}$ down a smooth slope inclined at $30°$. Find the work done by its weight and by the normal reaction.

Hint The weight acts down, and the block moves down by $5\sin 30°$. The normal reaction is perpendicular to the motion.

YOUR TURN · WE DO

B4 A $6\ \text{kg}$ box is pulled $10\ \text{m}$ up a slope inclined at $20°$ by a force of $50\ \text{N}$ parallel to the slope. A frictional force of $12\ \text{N}$ acts. Find the work done by each of the four forces on the box, and the total work done on it. [5 marks]

Answer .....

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C3 A $3\ \text{kg}$ ball is rolled up a curved ramp of length $6\ \text{m}$, from a height of $0.5\ \text{m}$ to a height of $2.1\ \text{m}$ above the floor. Find the work done against gravity, and explain why the length of the ramp is not needed. [4 marks]

Answer .....

C4 A $12\ \text{kg}$ sledge is dragged $50\ \text{m}$ up a slope at constant speed by a rope parallel to the slope. The slope is inclined at angle α to the horizontal, where $\sin\alpha = 0.1$. A resistance of $25\ \text{N}$ acts along the slope. Find the work done by the rope. [5 marks]

Answer .....

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PART 3 Finding the distance first

EXAMPLE 5 · I DO

A 5 kg box rests on a smooth horizontal floor. A horizontal force of 20 N acts on it. Find the work done by the force in the first 3 seconds.

Hint The box speeds up, so you do not yet know how far it moves. Find the acceleration from Newton's second law, then the distance from suvat.

YOUR TURN · WE DO

B5 A 4 kg trolley rests on a smooth horizontal floor. It is pushed by a horizontal force of 10 N. Find the work done by the force in the first 6 seconds. [4 marks]

Answer .....

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C5 A lift of mass $600\ \text{kg}$ is raised $15\ \text{m}$ by a cable. It accelerates upwards at $0.5\ \text{m s}^{-2}$ the whole way. Find the work done by the tension in the cable. [4 marks]

Answer .....

C6 A constant force of $15\ \text{N}$ acts on a $3\ \text{kg}$ particle on a smooth horizontal surface. The particle starts from rest and moves in the direction of the force for 4 seconds. Find (i) the impulse of the force, (ii) the work done by the force. Explain why the two answers have different units. [5 marks]

Answer .....

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C7 A $25\ \text{kg}$ box rests on rough horizontal ground. It is pulled by a force of $120\ \text{N}$ at $30°$ above the horizontal. A resistance of $40\ \text{N}$ acts. Find the work done by the $120\ \text{N}$ force in the first 5 seconds. [5 marks]

Answer .....

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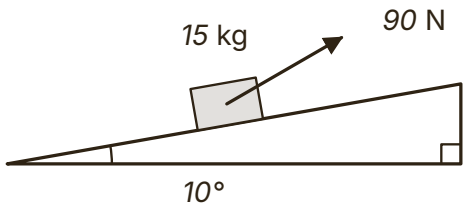
D1 A $15\ \text{kg}$ sledge is pulled from rest up a slope inclined at 10° to the horizontal. The rope makes 20° with the slope and its tension is $90\ \text{N}$. A frictional force of $30\ \text{N}$ acts along the slope.

(a) Show that the acceleration of the sledge is $1.94\ \text{m s}^{-2}$, correct to 3 significant figures. [3 marks]



(b) Hence find the distance the sledge moves up the slope in the first 5 seconds. [2 marks]

Answer .....

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(c) Find the work done by the tension in these 5 seconds. [2 marks]

Answer .....

(d) Find the work done against gravity in these 5 seconds. [2 marks]

Answer .....

(e) Find the work done against friction in these 5 seconds. [2 marks]

Answer .....

Total for D1: 11 marks

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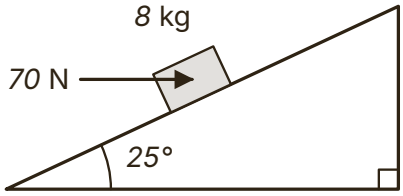
D2

> Alex writes: "The force is $70\ \text{N}$ and the box moves $6\ \text{m}$, so the work done by the force is $70 \times 6 = 420\ \text{J}$."

A $8\ \text{kg}$ box is pushed $6\ \text{m}$ up a smooth slope inclined at $25°$ to the horizontal by a horizontal force of $70\ \text{N}$.

(a) Explain why Alex is wrong. [2 marks]



(b) Find the work done by the horizontal force. [2 marks]

Answer .....

(c) Find the work done against gravity. [2 marks]

Answer .....

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(d) Find the normal reaction on the box, and state the work it does. [3 marks]

Answer .....

Total for D2: 9 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 A $20\ \text{kg}$ box rests on rough horizontal ground. It is pulled by a rope inclined at θ above the horizontal, with tension $100\ \text{N}$. A resistance of $50\ \text{N}$ acts. In the first 4 seconds the tension does $1500\ \text{J}$ of work. Find θ. [8 marks]

Answer .....

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Extension hints

Cover these with paper. Uncover one at a time.

E1

Hint 1 Write $c = \cos\theta$. The box speeds up, so first find its acceleration in terms of c.

Hint 2 Use suvat to write the distance moved in 4 seconds in terms of c.

Hint 3 Work done = the component of the tension along the ground × the distance. This gives a quadratic in c.

How did it go?

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

I can find the work done by a force along the motion or at an angle to it.	○ ○ ○
I can find the work done against gravity and against friction on a slope.	○ ○ ○
I can find a distance with Newton's second law and suvat, then the work done.	○ ○ ○
I can say which forces do no work, and tell work done from impulse.	○ ○ ○

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