Work done and energy transfer

4.5.2 · Forces · revision notes

When a force causes an object to move through a distance, work is done on the object and energy is transferred. You must use W = F s, convert between joules and newton-metres, and explain why doing work against friction makes objects warm up.

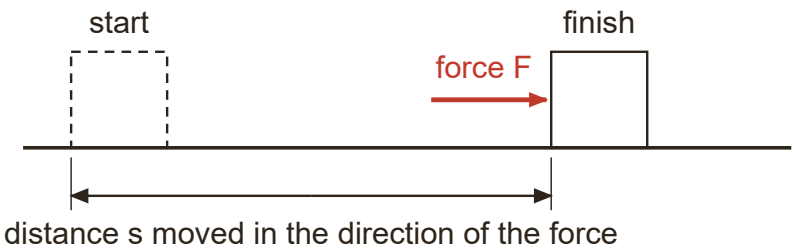
Key facts

- W = F s (work done = force × distance moved along the line of action of the force)
- 1 J = 1 N m
- Work done against friction transfers energy to the thermal store, so the temperature rises
- Grade 7+ only Work done lifting at steady speed = weight × height = m g h = gain in gravitational potential energy
- Units: W in J, F in N, s in m
- Work done = energy transferred
- No movement along the line of the force means no work is done

Notes

Doing work

- Work is done when a force causes an object to move through a distance.
- Work done = energy transferred. Both are measured in joules (J).
- work done = force × distance: **W = F s**
- W in joules (J), F in newtons (N), s in metres (m). The distance must be moved **along the line of action** of the force.



Work done = F × s: a force moving an object through a distance along the force's line of action.

- If the object does not move, no work is done, however hard you push.

Joules and newton-metres

- One joule of work is done when a force of one newton causes a displacement of one metre.
- So 1 joule = 1 newton-metre (1 J = 1 N m). A value in N m is the same number in J.
- Convert before calculating: kJ to J (× 1000), kN to N (× 1000), cm to m (÷ 100).

Work done against friction

- When an object slides against friction, or moves through air, work is done against the frictional force.
- This transfers energy to the thermal energy store of the object (and its surroundings), so its temperature rises.
- Examples: rubbing your hands together warms them; brake pads get hot when a car slows down; a sliding box warms the floor slightly.
- A cyclist at a steady speed does work against frictional forces: the kinetic store does not change, the cyclist's chemical store decreases and the thermal store of the surroundings increases.

Work and energy stores Grade 7+ only

- Lifting an object at a steady speed: the force needed equals its weight, so the work done = m g h, which equals its gain in gravitational potential energy.
- Braking: the work done by the braking force equals the kinetic energy the vehicle loses.

How to answer each type of question

Calculate work done 2 marks **Grade 4**

1. Check the force is in N and the distance in m.
2. Write W = F s and substitute.
3. Give the answer in J.

Example. A student pushes a box 4.5 m across a floor with a constant horizontal force of 120 N. Calculate the work done by the student.

Model answer.

W = 120 × 4.5 (1)
W = 540 J (1)

Rearrange to find force or distance 3 marks **Grade 5**

1. Convert units first (kJ to J).
2. Substitute into W = F s.
3. Rearrange and calculate, with a unit.

Example. A crane does 36 kJ of work lifting a load a vertical height of 15 m at a steady speed. Calculate the force the crane exerts on the load.

Model answer.

36 kJ = 36 000 J (1)
36 000 = F × 15 (1)
F = 2400 N (1)

Explain heating caused by friction

2 to 3 marks | Grade 5

1. Identify the friction.
2. Say that work is done against friction.
3. Say that energy is transferred to the thermal store, so the temperature rises.

Example. A child slides down a playground slide. Afterwards, the surface of the slide and the child's clothes are warmer.
Explain why.

Model answer.

There is friction between the child and the slide (1).
Work is done against the friction (1)
so energy is transferred to the thermal energy store of the slide and the clothes, and their temperature increases (1).

Multi-step: work done and kinetic energy

4 marks | Grade 7

1. Calculate the energy in the relevant store (e.g. $E_k = ½ m v^2$).
2. Set the work done equal to the energy transferred.
3. Use W = F s to find the unknown.

Example. A car of mass 900 kg is travelling at 20 m/s. The driver brakes and the car stops. The average braking force is 6000 N.
Calculate the braking distance.

Model answer.

$E_k = 0.5 \times 900 \times 20^2$ (1)
$E_k = 180\,000$ J (1)
work done by the brakes = kinetic energy lost, so $180\,000 = 6000 \times s$ (1)
$s = 30$ m (1)

Don’t lose marks

- Using a distance in cm, or a force in kN, without converting.
- Using the wrong distance: it must be the distance moved in the direction of the force (e.g. the vertical height when lifting).
- Saying friction 'creates heat energy'. Say that work done against friction transfers energy to the thermal store and the temperature rises.
- Confusing work done (in J) with power (in W). Power is the rate of doing work.

More tips

Memory tricks

- Work done = energy transferred, so many energy questions are really 'work done' questions in disguise.
- N × m = N m = J. If you get N m in a work question, you can write J.
- Formula triangle: W on top, F and s underneath.
- Three different W's: W for work done (J), W for weight (N), and W for watts (the unit of power). Read carefully.

Exam technique

- Practise using W = F s, with distance measured along the force.
- Show the equation, the substitution and the answer with a unit. Each can earn a mark.
- In 'explain' questions about warming, use the phrase 'work done against friction'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

State that work done is energy transferred

When a force moves an object through a distance, energy is transferred and work is done.

Grade 4

Calculate work done using W = F s

For example, 50 N × 3.0 m = 150 J.

Grade 5

Find force or distance from work done

F = W ÷ s and s = W ÷ F.

Grade 5

Convert between joules and newton-metres

1 J = 1 N m, so 250 N m of work is 250 J.

Grade 5

Explain heating by work done against friction

Work done against friction transfers energy to the thermal store, so the temperature of the object rises.

Grade 7

Link work done to changes in energy stores

Work done by brakes equals the kinetic energy lost; work done lifting an object equals its gain in gravitational potential energy.

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