

Changes in energy

4.1.1.2 · Energy · revision notes

How to calculate the energy in the kinetic, gravitational potential and elastic potential stores. These are some of the most common calculations on Paper 1: 2 marks for a straight substitution, and 3 to 5 marks when you must convert units, rearrange, or link two stores to find a speed or a height.

Key facts

- Kinetic energy: $E_k = \frac{1}{2} m v^2$ (recall)
- Elastic potential energy: $E_e = \frac{1}{2} k e^2$ (on the equations sheet)
- $g = 9.8 \text{ N/kg}$ on Earth (given in the question)
- Gravitational potential energy: $E_p = m g h$ (recall)
- Units: E in J, m in kg, v in m/s, g in N/kg, h in m, k in N/m, e in m
- Double v or $e \rightarrow 4 \times$ the energy; double m , h or $k \rightarrow 2 \times$ the energy

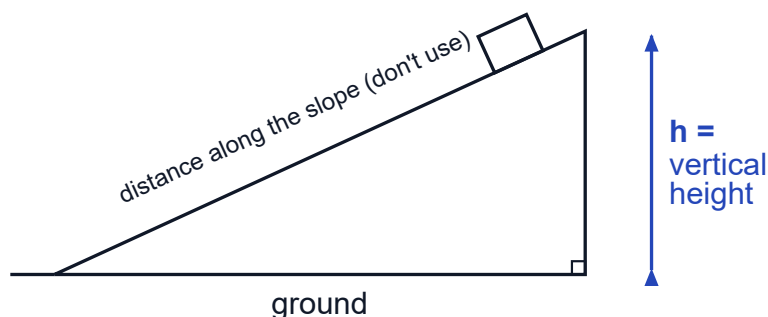
Notes

Kinetic energy

- A moving object has energy in its **kinetic store**: $E_k = \frac{1}{2} m v^2$
- E_k = kinetic energy in joules (J), m = mass in kilograms (kg), v = speed in metres per second (m/s).
- Only the speed is squared. Doubling the mass doubles the kinetic energy; doubling the speed makes it 4 times bigger.

Gravitational potential energy

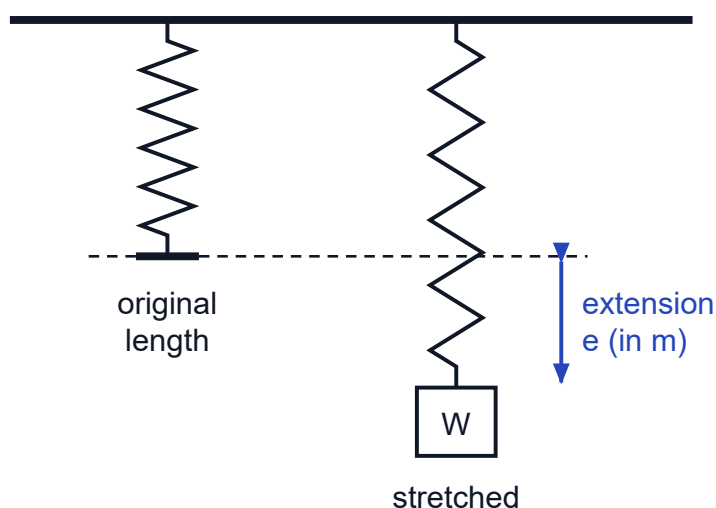
- Raising an object increases the energy in its **gravitational potential store**: $E_p = m g h$
- g = gravitational field strength in N/kg (9.8 N/kg on Earth; the question gives you the value to use).
 h = change in height in metres (m).
- Use the vertical height gained or lost, not the distance travelled along a slope.



In $E_p = m g h$, h is the vertical height gained.

Elastic potential energy

- Stretching or squashing a spring stores energy in its **elastic potential store**: $E_e = \frac{1}{2} k e^2$ (this equation is on the equations sheet).
- k = spring constant in N/m, e = extension (or compression) in metres (m).



The extension e is the increase in length, measured from the original length.

- It only works if the **limit of proportionality** has not been exceeded.
- Doubling the extension makes the stored energy 4 times bigger.

How to answer each type of question

Calculate the kinetic energy

2 marks

Grade 5

1. Write $E_k = \frac{1}{2} m v^2$.
2. Check the mass is in kg and the speed is in m/s.
3. Substitute, square the speed first, then multiply.
4. Give the answer with the unit J.

Example. A cyclist and her bicycle have a total mass of 85 kg. She rides at a speed of 6.0 m/s. Calculate the kinetic energy of the cyclist and bicycle.

Model answer. $E_k = 0.5 \times 85 \times 6.0^2$ (1)

$E_k = 1530 \text{ J}$ (1)

Don't lose marks

- ✗ Squaring the whole of $\frac{1}{2} m v$ instead of just v .
- ✗ Leaving mass in grams or distances in centimetres.
- ✗ Using the distance along a slope instead of the vertical height.
- ✗ Forgetting the square root at the end when finding a speed or an extension.
- ✗ Rounding the first step (e.g. 1.9 J instead of 1.8816 J), which makes the final answer wrong.

More tips

Memory tricks

- Calculator: type $0.5 \times m \times v$ and then press x^2 straight after the v , so only the speed is squared.
- Sense check: a person walking (70 kg at 1.5 m/s) has about 80 J of kinetic energy; a car at motorway speed has hundreds of thousands of joules.
- 'Squared means 4 times': double the speed or the extension and the energy goes up 4 times.
- For a falling object with no energy dissipated the mass cancels out, so $v = \sqrt{2 g h}$. Use it to check your answer.

Exam technique

- Write the equation, then the substitution, then the answer. The substitution often earns a mark even if you slip later.
- Look for 'assume no energy is dissipated': it tells you to set the energy in one store equal to the other.
- In a 'show that' question, give your answer to at least one more significant figure than the value you are shown.
- Always give a unit: J for energy, m/s for speed, m for a height or an extension.

What each grade needs

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

Grade 3**Recall the kinetic and gravitational energy equations**

$E_k = \frac{1}{2} m v^2$ and $E_p = m g h$: the specification says you must be able to recall both.

Grade 4**Calculate gravitational potential energy**

Multiply mass (kg) $\times$ gravitational field strength (N/kg) $\times$ height (m) to get the energy in joules.

Grade 5**Calculate kinetic energy**

Square the speed first, then multiply by the mass and by 0.5.

Grade 5**Calculate elastic potential energy of a spring**

Use $E_e = \frac{1}{2} k e^2$ with the extension in metres, as long as the limit of proportionality is not exceeded.

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