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: $E_k = ½ m v^2$ (on the equations sheet)
- Elastic potential energy: $E_e = ½ k e^2$ (on the equations sheet)
- g = 9.8 N/kg on Earth (given in the question)
- Grade 7+ only No energy dissipated: energy lost from one store = energy gained by another
- Gravitational potential energy: $E_p = m g h$ (on the equations sheet)
- 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 → 4 × the energy; double m, h or k → 2 × the energy
- Grade 7+ only $v = \sqrt{\frac{2E_k}{m}}$ and $e = \sqrt{\frac{2E_e}{k}}$

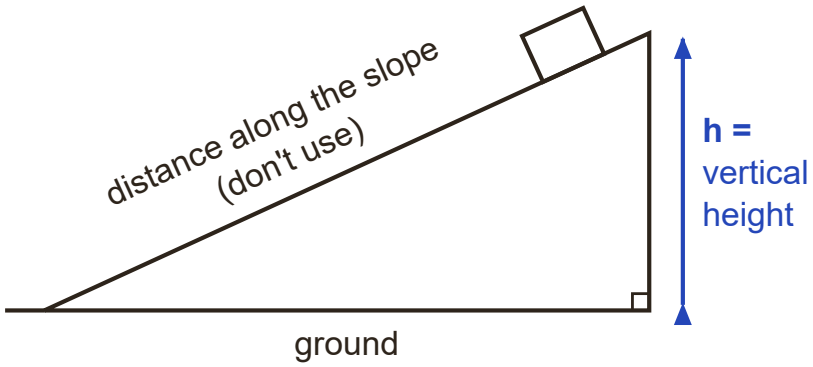
Notes

Kinetic energy

- A moving object has energy in its **kinetic store**: $E_k = ½ m v^2$
- 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.
- To find the speed, rearrange: $v = \sqrt{\frac{2E_k}{m}}$ Grade 7+ only

Gravitational potential energy

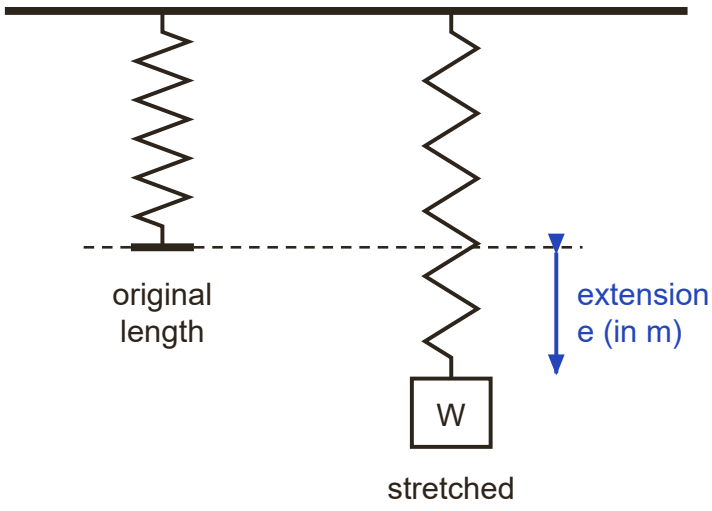
- Raising an object increases the energy in its **gravitational potential store**: $E_p = m\ g\ h$
- g = gravitational field strength in N/kg (9.8 N/kg on Earth; the question gives you the value to use).
  h = change in height in metres (m).
- Use the vertical height gained or lost, not the distance 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**: $E_e = ½\ k\ e^2$ (this equation is on the equations sheet).
- k = spring constant in N/m, e = extension (or compression) in metres (m).

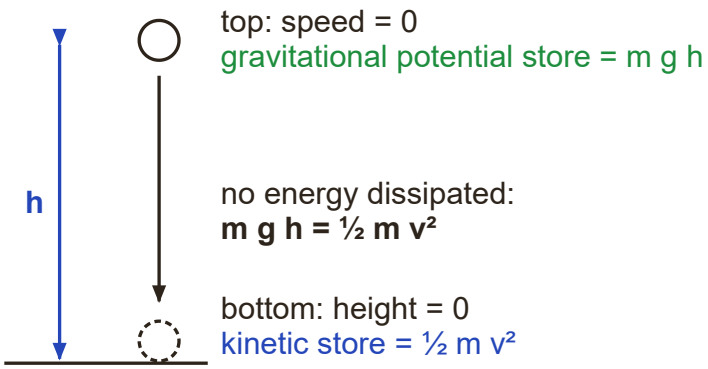


The extension e is the increase in length, measured from the original length.

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

Linking two stores Grade 7+ only

- If no energy is dissipated, the energy lost from one store equals the energy gained by another.
- A falling object: gravitational potential energy lost = kinetic energy gained. A spring firing a ball: elastic potential energy of the spring = kinetic energy of the ball.
- Investigation: release a trolley from rest down a ramp, measure the vertical drop h and the final speed (light gate), then compare m g h with ½ m v^2. E_k comes out less because of friction.



Falling object: GPE lost = KE gained, so you can find the speed.

- Work in two steps: calculate the energy in the first store, then put that value into the equation for the second store.
- In real life some energy is dissipated by air resistance or friction, so the kinetic energy gained is less than this.

How to answer each type of question

Calculate the kinetic energy 2 marks Grade 5

1. Write $E_k = ½ m v^2$.
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)

$E_k = 1530$ J (1)

Calculate the gravitational potential energy (with unit conversions) 2 marks **Grade 6**

1. Convert grams to kg and centimetres to m.
2. Use the vertical change in height.
3. Substitute into $E_p = m\ g\ h$, using the value of g given in the question.

Example. A student lifts a bag of mass 2400 g from the floor onto a shelf 150 cm above the floor.
gravitational field strength = 9.8 N/kg
Calculate the increase in the gravitational potential energy store of the bag.

Model answer.

$E_p = 2.4 \times 9.8 \times 1.5$ (1)

$E_p = 35$ J (35.28 J) (1)

Calculate the elastic potential energy 2 marks **Grade 6**

1. Convert the extension to metres.
2. Substitute into $E_e = ½\ k\ e^2$, squaring only the extension.
3. Give the answer with the unit J.

Example. A spring has a spring constant of 40 N/m. It is stretched by 15 cm. The limit of proportionality is not exceeded.
Calculate the elastic potential energy stored in the spring.

Model answer.

$E_e = 0.5 \times 40 \times 0.15^2$ (1)

$E_e = 0.45$ J (1)

Calculate a speed by linking two energy stores

4 marks | Grade 8

1. Calculate the energy in the first store (here $E_p = m\ g\ h$).
2. Set it equal to the energy gained by the second store (here $E_k = \frac{1}{2}\ m\ v^2$).
3. Rearrange to find v^2.
4. Take the square root, rounding only at the end.

Example. A ball of mass 0.060 kg is dropped from a height of 3.2 m.
Assume that no energy is dissipated as the ball falls.
gravitational field strength = 9.8 N/kg
Calculate the speed of the ball just before it hits the ground.

Model answer.

$E_p = 0.060 \times 9.8 \times 3.2 = 1.8816$ J (1)

$1.8816 = 0.5 \times 0.060 \times v^2$ (1)

$v^2 = 1.8816 \div 0.030 = 62.72$ (1)

$v = 7.9$ m/s (1)

Don’t lose marks

- Squaring the whole of ½ 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 × m × 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

$E_k = ½ m v^2$ and $E_p = m g h$: both are on the Physics Equations Sheet, but you must pick the right one, know each symbol and unit, and rearrange it.

Grade 4

Calculate gravitational potential energy

Multiply mass (kg) × gravitational field strength (N/kg) × 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 $E_e = ½ k e^2$ with the extension in metres, as long as the limit of proportionality is not exceeded.

Grade 6

Convert units before you substitute

Change grams to kilograms, centimetres to metres and kilojoules to joules first.

Grade 7

Rearrange to find speed, height or extension

E.g. $h = E_p \div (m \times g)$, or $v = \sqrt{(2E_k \div m)}$, taking the square root last.

Grade 8

Link energy stores in multi-step problems

Use 'energy lost from one store = energy gained by another' to find a speed or a height.

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