

Energy Notes

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Energy is one of the most fundamental concepts in physics, as it is the driving force behind absolutely every change or process in the whole universe. We use the word 'energy' a lot in everyday life, but what is it?

What is energy? Energy is a quantity that must be transferred to get things done. It is measured in Joules (J).

What is a quantity? In physics, a quantity is a measurement that has a size. So mass is a quantity as it is measured in grams or kilograms or distance is also a quantity as it is measured in metres (m).

There are **eight types of energy** store that we need to know about these are:

1. **Kinetic.**
2. **Elastic potential.**
3. **Gravitational potential.**
4. **Thermal (moving heat).**
5. **Electrostatic.**
6. **Chemical.**
7. **Magnetic.**
8. **Nuclear potential**

The Law of conservation of energy: states that energy cannot be created or destroyed but that it can be transferred from one form to another.

Energy Transfers

In any energy transfer question, we are dealing with a system. Whether it's a television, a computer or a human. These are all systems. In a system there is always an energy input and output. A system is an object or group of objects.

Energy transfers look at:

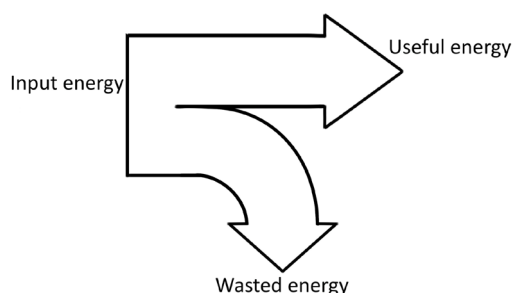
- **Input energy** – the energy put into a system
- **Output energy** – the energy that comes out of a system.

Output energy can be split into two types, useful energy (what we want) and wasted energy (what we don't want). Take a look at the following examples:

A light bulb:		A person running:	
Energy input	Energy output	Energy input	Energy output
Electrical	→ light + thermal	Chemical	→ kinetic + thermal + sound
100 J	→ 10 J + 90 J	500 J	→ 300 J + 150 J + 50 J
A plane taking off:			
	Energy input		Energy output
	Chemical	→	kinetic + gravitational potential + sound
	10 000 J	→	6000 J + 2000 J + 2000 J

Sankey Diagrams

A Sankey diagram is a visual representation of energy transfers. It makes it easy to see at a glance how much energy is put into a system, how much is useful, and how much is wasted. The figure shows a typical Sankey diagram.



When drawing or reading these what do we need to know?

1. **Width = energy:** the thickness (width) of the arrow represents the amount of energy.
2. **Scale:** they are drawn to scale. For example, 1 little square on graph paper might represent 10 Joules.
3. **Direction matters:** Input energy always enters from the left. Useful energy continues going straight on to the right. Wasted energy curves downwards.

Reducing Wasted Energy

In mechanical systems, energy is usually wasted as thermal energy due to friction. We can reduce this wasted energy **(and increase efficiency)** using **two main methods**:

Lubrication: oiling or greasing moving parts reduces friction. This means less kinetic energy is lost as thermal energy.

Thermal insulation: To stop buildings or objects from losing heat, we surround them with thick materials that have a low thermal conductivity. This slows down the rate at which thermal energy is transferred to the surroundings.

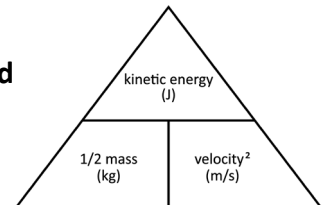
Kinetic Energy

Kinetic energy is the energy that a moving object has. When an object is moving faster it will have more kinetic energy.

The equation for kinetic energy is:

Kinetic energy = half of the mass × velocity squared

$$E_k = \frac{1}{2}(m) \times v^2$$



Where: E_k = kinetic energy in Joules (J) m = mass in kg v = velocity in meters per second (m/s)

This equation is given to you in the GCSE exam papers so you do not need to learn it. But, please make sure that you are familiar with it and comfortable using it.

Example calculations

An object has a mass of 500 kg and has a velocity of 2 m/s. Calculate its kinetic energy.

$$E_k = \frac{1}{2}(m) \times v^2$$

$$E_k = \frac{1}{2}(500) \times 2^2 \quad E_k = 1000 \text{ J}$$

An object has a mass of 15.4 g and a kinetic energy of 4000 J. Calculate the velocity of the object.

$$E_k = \frac{1}{2}(m) \times v^2$$

$$v^2 = E_k \div \frac{1}{2}(m) \quad v^2 = 4000 \div \frac{1}{2}(0.0154)$$

$$v^2 = 519\,480.5 \quad v = \sqrt{519\,480.5} \quad v = 720.7 \text{ m/s}$$

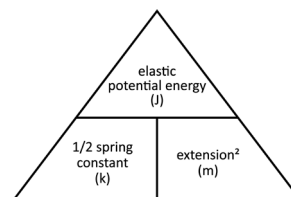
Elastic Potential Energy

Elastic potential energy is the energy that a stretched object has.

The equation for elastic potential energy is:

Elastic potential energy = half of the spring constant × extension squared

$$E_e = \frac{1}{2}(k) \times e^2$$



E_e = elastic potential energy in Joules (J) k = spring constant (N/m) e = extension in metres (m)

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Example calculations

A spring is extended by 0.025 m and has a spring constant of 500 N/m. Calculate its elastic potential energy.

$$E_e = \frac{1}{2}(k) \times e^2$$

$$E_e = \frac{1}{2}(500) \times 0.025^2$$

$$E_e = 0.156 \text{ J}$$

250 J of energy was applied to a spring with a spring constant of 150 N/m. Calculate the extension that would occur.

$$E_e = \frac{1}{2}(k) \times e^2$$

$$e^2 = E_e \div \frac{1}{2}(k)$$

$$e^2 = 250 \div \frac{1}{2}(150) \quad e^2 = 3.3$$

$$e = \sqrt{3.3} \quad e = 1.83 \text{ m}$$

Gravitational Potential Energy

Gravitational potential energy is the energy that is transferred to an object when it is lifted up.

The equation for gravitational potential energy is:

Gravitational potential energy = mass × gravitational field strength × height

$$E_p = m \times g \times h$$

E_p = gravitational potential energy (J) m = mass (kg) g = gravitational field strength h = height (m)

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Example calculations

A ball with a mass of 200g is raised by a height of 3 m.
Take gravity as 10 m/s².
Calculate its gravitational potential energy.

$$\begin{aligned} E_p &= m \times g \times h \\ E_p &= 0.200 \times 10 \times 3 \\ E_p &= 6 \text{ J} \end{aligned}$$

A block of stone of mass 600 kg gains 36000 J of GPE.
How high has it been raised?
Assume that gravity is 9.81 m/s².

$$\begin{aligned} E_p &= m \times g \times h \\ 36\,000 &= 600 \times 9.81 \times h \\ 36\,000 \div 5886 &= h \quad h = 6.1 \text{ m} \end{aligned}$$

Power

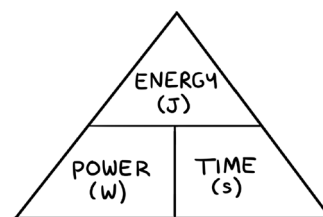
Power describes how much energy is transferred per second.

The equation for power is:

Power = energy ÷ time

$$P = e \div t$$

P = power(W) e = energy (J) t = time (s)



This equation is given to you in the GCSE exam papers so you do not need to learn it.

Example calculations

Over 15 seconds, a student uses 600 J of energy to push a toy box. Calculate the student's power.

$$\begin{aligned} P &= e \div t \\ P &= 600 \div 15 \\ P &= 40 \text{ W} \end{aligned}$$

An appliance uses 20 000 J of energy in 40 seconds.
What is the power rating of the appliance?

$$\begin{aligned} P &= e \div t \\ P &= 20\,000 \div 40 \\ P &= 500 \text{ W} \end{aligned}$$

Efficiency

Efficiency a measure of how much energy is transferred to useful energy in a system.

The equation for efficiency is:

Efficiency = (useful energy ÷ total energy) × 100 **or** Efficiency = (useful power ÷ total power) × 100

This equation is given to you in the GCSE exam papers so you do not need to learn it.

Example calculations

A light bulb receives 120 J of electrical energy.
This is converted to 30 J of light energy and 90 J of thermal energy.
Calculate the efficiency of the light bulb.

$$\begin{aligned} \text{Efficiency} &= (30 \div 120) \times 100 \\ \text{Efficiency} &= 25 \% \end{aligned}$$

An appliance has an efficiency rating of 45 %.
2000 J of electrical energy was supplied to the appliance.
Calculate the useful energy supplied to the appliance.

$$\begin{aligned} \text{Efficiency} &= (\text{useful energy} \div \text{total energy}) \times 100 \\ 45 &= (\text{useful energy} \div 2000) \times 100 \\ \text{useful energy} &= (45 \times 2000) \div 100 \\ \text{useful energy} &= 900 \text{ J} \end{aligned}$$

Work Done

“**Work done**” is a fun concept in physics. It’s really just another way of saying the energy transferred in a system.

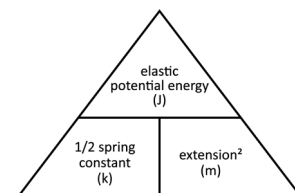
Let’s explain it! 😊 Whenever a force is used to move an object, energy is transferred to that object. We can then say that work is done on that object.

Work is done if the object moves **in the same direction as the force that was applied**. (If you push against a solid brick wall and it doesn't move, you might get tired, but your work done is zero!)

The equation for work done is:

$$\text{Work done} = \text{Force} \times \text{distance}$$

$$W = F \times s$$



Where: **W** = work done in Joules (J) **F** = force in Newtons (N) **s** = the distance in meters (m)

This equation is given to you in the GCSE exam papers so you do not need to learn it. But, please make sure that you are familiar with it and comfortable using it.

Exam note: watch out for questions where they give us the distance as something other than metres (m). Like cm or km or mm if they are being really mean, we need to change these to metres to do the question correctly.

Let’s look at a few examples 😊

Example 1: A worker applies a constant horizontal force of **400 N** to push a heavy crate a distance of **15 m** across a warehouse floor. Calculate the work done by the worker.

$$W = F \times s$$

$$W = 400 \text{ N} \times 15 \text{ m}$$

$$\text{Work Done} = \mathbf{6000 \text{ J}}$$

Example 2: A car's brakes do 45 kJ of work to overcome a frictional force of 1800 N. Calculate the braking distance of the car.

Watch out! Convert the kilojoules into Joules before doing the question.

$$45 \text{ kJ} \times 1000 = 45,000 \text{ J}$$

$$W = F \times s$$

$$s = \frac{W}{F}$$

$$s = \frac{45000}{1800}$$

$$s = 25 \text{ m}$$

That’s it! Work done doesn’t get any more difficult than that really! Can the questions get longer? Of course, that’s how they make things more challenging but they can’t change work done itself 😊