Potential and Kinetic Energy
Potential and Kinetic Energy

Changes in stored energy

Gravitational potential energy

Kinetic energy

Energy transfers in falling objects

Summary activities
A **system** is an object or a group of objects. It is a useful way of thinking about some physics problems.

Energy can take many different forms. For example:

- moving objects have **kinetic energy**
- stretched or compressed objects have **elastic potential energy**
- objects in a gravitational field have **gravitational potential energy**.

When something about a system **changes**, the way that **energy** is stored in it can also change from one form to another.
Changes in energy

Can you describe the way that energy is changing in these systems?

An arrow fired from a bow:
An archer draws back the bow string, storing **elastic potential energy**. When they release it, the arrow flies forwards and upwards.
Changes in energy

Can you describe the way that energy is changing in these systems?

A basketball hitting the floor:
An athlete scores a basket. As the basketball falls, its **gravitational potential energy** is converted to **kinetic energy**. It compresses (squashes) when it hits the floor, and the kinetic energy is stored as **elastic potential energy**.

- **gravitational potential energy** → **kinetic energy** → **elastic potential energy**
Can you describe the way that energy is changing in these systems?

A car braking at a traffic light:

When the brakes are applied, friction increases. The **kinetic energy** of the wheels is transferred into **sound energy** and **heat (thermal) energy**.
Changes in energy

Can you describe the way that energy is changing in these systems?

Water boiling in an electric kettle:

When the kettle is switched on, current flows through the heating element. Electrical energy is converted into sound energy and heat (thermal) energy.
Potential and Kinetic Energy

- Changes in stored energy
- Gravitational potential energy
- Kinetic energy
- Energy transfers in falling objects
- Summary activities
What is gravitational potential energy?

When an object is lifted upwards, the force doing the lifting does work against the force of gravity.

For example, this crane does work lifting this box.

The work done is stored as gravitational potential energy ($E_p$). It is called potential energy because it has the potential to be transferred into other forms of energy later.

For example, if the hook broke and the box fell, the stored gravitational potential energy would be converted to kinetic energy.
How is GPE calculated?

The GPE of an object can be calculated using this equation:

\[
GPE = \text{mass} \times \text{gravitational field strength} \times \text{height}
\]

or

\[
E_p = mgh
\]

- Mass \((m)\) is measured in \text{kilograms (kg)}.
- Gravitational field strength \((g)\) is measured in \text{newtons per kilogram (N/kg)}, and is usually assumed to be 10 N/kg close to the surface of Earth.
- Height \((h)\) is measured in \text{metres (m)}.
- Gravitational potential energy \((E_p)\) is measured in \text{joules (J)}. 

Height \((h)\) is measured in \text{metres (m)}.
Factors affecting GPE
A plane with a mass of 5,000 kg travels at a height of 10 km above the ground.

How much gravitational potential energy does the plane have?

Assume a value of 10 N/kg for g.

\[
\text{GPE} = \text{mass} \times \text{gravitational field strength} \times \text{height}
\]

\[
= 5,000 \times 10 \times 10,000
\]

\[
= 500,000,000 \text{ J} = 500 \text{ MJ}
\]
Calculating GPE question 2

An orange with a mass of 250g falls 2.5m from its branch to the ground.

How much **GPE** will the orange have lost when it hits the ground?

Assume a value of 10 N/kg for g.

\[
\text{GPE lost} = \text{mass} \times \text{gravitational field strength} \times \text{change in height}
\]

\[
= 0.25 \times 10 \times 2.5
\]

\[
= 6.25 \text{J}
\]
You will need this equation to answer the following questions about GPE, mass and height:

\[
\text{GPE} = \text{mass} \times \text{gravitational field strength} \times \text{height}
\]

Press "start" to begin.
Potential and Kinetic Energy

- Changes in stored energy
- Gravitational potential energy
- Kinetic energy
- Energy transfers in falling objects
- Summary activities
What is kinetic energy?

The word ‘kinetic’ comes from the Greek word ‘kinesis’, meaning motion.

**Kinetic energy** is the energy an object has because it is moving.

All moving things have kinetic energy, but the amount of energy they have is not just dependent on how fast they are moving.

What other factors might affect the kinetic energy of a moving object?
How is kinetic energy calculated?

The kinetic energy ($E_k$) of an object can be calculated using this equation:

$$E_k = \frac{1}{2} \times \text{mass} \times \text{velocity}^2$$

or

$$E_k = \frac{1}{2}mv^2$$

- **Mass**, $m$, is measured in **kilograms** (kg).  
- **Velocity**, $v$, is measured in **metres per second** (m/s).  
- **Kinetic energy**, $E_k$, is measured in **joules** (J).
A car with a mass of 1,000 kg travels at a velocity of 20 m/s.

What is the kinetic energy of the car?

\[
\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{velocity}^2
\]

\[
= \frac{1}{2} \times 1,000 \times 20^2
\]

\[
= 200,000 \text{ J} = 200 \text{ kJ}
\]
If you know the kinetic energy of an object, you can rearrange the equation in order to calculate its **mass** or **velocity**.

\[ E_k = \frac{1}{2}mv^2 \]

**Rearranged to calculate mass:**

\[ m = \frac{2E_k}{v^2} \]

**Rearranged to calculate velocity:**

\[ v = \sqrt{\frac{2E_k}{m}} \]
A lorry has a mass of 20,000 kg. If its kinetic energy is 2.25 MJ, at what velocity is it travelling?

\[ E_k = \frac{1}{2}mv^2 \]

velocity = \[ \sqrt{\frac{2E_k}{\text{mass}}} \]

= \[ \sqrt{\frac{2 \times 2,250,000}{20,000}} \]

= 15 m/s
You will need this equation to answer the following questions about kinetic energy, mass, and velocity:

\[ \text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{velocity}^2 \]

Click "start" to begin.
Potential and Kinetic Energy

- Changes in stored energy
- Gravitational potential energy
- Kinetic energy
- Energy transfers in falling objects
- Summary activities
Energy transfers within a system

Imagine a tennis ball with a mass of 60 g dropped from a height of 50 cm.

Initially, the tennis ball has some **gravitational potential energy** ($E_p$):

$$E_p = mgh$$

$$= 0.06 \times 10 \times 0.5$$

$$= 0.3 \text{ J}$$

And **no kinetic energy** ($E_k$), because it is not moving.

The **total** energy in the system is **0.3 J**.
Energy transfers within a system

Imagine a tennis ball with a mass of 60 g dropped from a height of 50 cm.

When it is dropped, $E_p$ is converted to $E_k$.

As it falls, $E_p$ decreases and $E_k$ increases, but the total energy of the system stays the same.

When it hits the ground, $E_p$ is reduced to zero. All of the gravitational potential energy has been transferred to kinetic energy.

<table>
<thead>
<tr>
<th>$E_p = 0 \text{ J}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_k = 0.3 \text{ J}$</td>
</tr>
<tr>
<td>total energy = 0.3 J</td>
</tr>
</tbody>
</table>


Energy transfers in rollercoasters

What happens to the $E_k$ and $E_p$ of a rollercoaster?
The relationship between GPE and KE

As the rollercoaster loses height, the stored gravitational potential energy is transferred into kinetic energy.

\[ E_p \text{ lost} = E_k \text{ gained} \]

This equation is only true if air resistance and friction are ignored.

In reality, \( E_p \) would also be transferred into heat and sound energy, so the \( E_k \) of the rollercoaster would be a bit less than the \( E_p \) lost.
Potential and Kinetic Energy

- Changes in stored energy
- Gravitational potential energy
- Kinetic energy
- Energy transfers in falling objects
- Summary activities
Multiple-choice quiz