

Energy

We will start the Energy section with definitions and formulae which you can write up in your PHYSICS notebooks.

Energy is the capacity (ability) for doing work.

Symbol: E

Unit: Joules, J

Kinetic Energy: energy an object possesses as a result of its motion

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

Where: E_k = kinetic energy (J)

m = mass (kg)

v = velocity (m.s^{-1})

Velocity and speed have the same units and can be regarded as the same thing at this stage...more on velocity later in the year ☺

Potential Energy: stored energy

A body possesses potential energy, E_p , when it has the ability to do work due to:

- its **position** (e.g. gravity)
- or its **form** (e.g. coiled spring)

Gravitational Potential Energy:

energy an object has because of its position in the gravitational field relative to the surface of the Earth

$$E_p = mgh$$

Where: E_p = gravitational potential energy (J)

m = mass (kg)

g = gravitational acceleration (constant) = $9,8 \text{ m.s}^{-2}$

h = height above Earth's surface (m)

Law of Conservation of Energy:

The total energy of an isolated system remains constant.

Isolated system: a system that does not interact with its surroundings;
i.e. no transfer of energy or mass between system and surroundings

This means that Energy cannot be created or destroyed, but is merely transformed from one form to another.

Mechanical Energy: the sum of the gravitational potential energy and kinetic energy

$$E_{\text{mech}} = E_p + E_k$$

Conservation of Mechanical Energy:

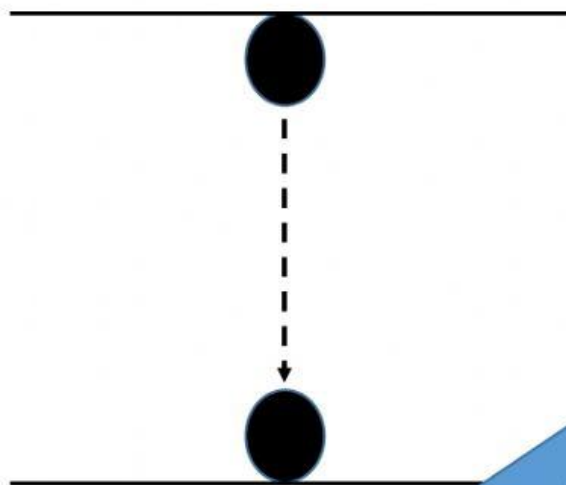
The total mechanical energy in an isolated system remains constant.

e.g. as an object falls, decrease in E_p = increase in E_k
(as long as there are no outside forces like friction)

The principle of conservation of mechanical energy allows us to do calculations in the following scenarios:

1. **An object that falls freely** (dropped from zero velocity)

If E_{mech} stays constant at all times, then $E_{\text{mech (top)}} = E_{\text{mech (bottom)}}$



$$\begin{aligned} E_{\text{mech (top)}} &= E_k + E_p \\ &= 0 + mgh \end{aligned}$$

$$\begin{aligned} E_{\text{mech(middle)}} &= E_k + E_p \\ &= \frac{1}{2}mv^2 + mgh \end{aligned}$$

$$\begin{aligned} E_{\text{mech (bottom)}} &= E_k + E_p \\ &= \frac{1}{2}mv^2 + 0 \end{aligned}$$

Note: at the top there is no motion (only E_p); at the bottom there is no height (only E_k); in the middle there is $E_p + E_k$

NB!

The key point in these calculations is that E_{mech} at ANY POINT in the motion is the same value. So in the above example,

$$E_{\text{mech}}(\text{top}) = E_{\text{mech}}(\text{middle}) = E_{\text{mech}}(\text{bottom})$$

Example 1:

A tennis ball, with a mass of 0,2 kg is dropped from a 50 m high building. (If there is no air friction)

Calculate:

1.1 the E_k of the ball at the top of the building

(Hint: BEFORE it is dropped)

$$E_k(\text{top}) = \frac{1}{2} mv^2 = \frac{1}{2} \times \quad \times \quad 0 \text{ m.s}^{-1}$$
$$= \quad \text{J}$$

1.2 the E_p at at the top of the building

$$E_p(\text{top}) = mgh = \quad \times 9,8 \times \quad$$
$$= \quad \text{J}$$

1.3 the E_{mech} at the top of the building

$$E_{\text{mech}}(\text{top}) = E_p + E_k$$
$$= \quad + \quad$$
$$= \quad \text{J}$$

1.4 the E_{mech} at the bottom of the building

$$E_{\text{mech}}(\text{bottom}) = E_{\text{mech}}(\text{top}) = \quad \text{J}$$

Only enter
numbers – no
units

Already
calculated above

1.5 the E_p at the bottom of the building

$$E_p(\text{bottom}) = mgh = \quad \times \quad \times$$
$$= \quad \text{J}$$

1.6 the E_k at the bottom of the building (the split second before it hits the ground)

$$E_k(\text{bottom}) = \frac{1}{2} mv^2$$

BUT WE DON'T KNOW "v"So we do this:

$$E_{\text{mech}}(\text{bottom}) = \quad \text{J} \quad \text{.....from 1.4}$$

$$E_{\text{mech}}(\text{bottom}) = E_p + E_k(\text{bottom})$$

Therefore:

$$E_k(\text{bottom}) = E_{\text{mech}}(\text{bottom}) - E_p \quad \text{.....remember } E_p(\text{bottom}) = 0$$

$$E_k(\text{bottom}) = \quad \text{J}$$

1.7 the speed of the ball just before it hits the ground

$$E_k(\text{bottom}) = \frac{1}{2} mv^2$$

$$= \frac{1}{2} \times \quad \times v^2$$

$$\frac{\quad \times 2}{\quad} = v^2$$

$$v^2 = \quad \text{.....now square root!}$$

$$v = \quad \text{m.s}^{-1}$$

Example 2

A tennis ball, with a mass of 0,2 kg is dropped from a 40 m high bridge. (If there is no air friction)

Calculate:

2.1 the E_k of the ball at the top of the building

$$E_k (\text{top}) = \quad \text{J}$$

2.2 the E_p at the top of the building

$$E_p (\text{top}) = mgh$$

$$= \quad \times \quad \times$$

$$= \quad \text{J}$$

2.3 the E_{mech} at the top of the building

$$E_{\text{mech}} (\text{top}) = E_p + E_k$$

$$= \quad +$$

$$= \quad \text{J}$$

2.4 the E_{mech} of the ball at a height of 20 m

$$E_{\text{mech}} (20\text{m}) = \quad \text{J}$$

2.5 the E_p of the ball at a height of 20 m

$$E_p (20\text{m}) = mgh$$

$$= \quad \times \quad \times$$

$$= \quad \text{J}$$



2.6 the E_k of the ball at a height of 20 m

$$E_{\text{mech}}(20\text{m}) = \quad \text{J}$$

$$E_{\text{mech}}(20\text{m}) = E_p + E_k$$

$$J = \quad + E_k$$

$$E_k = \quad \text{J}$$

2.7 the speed of the ball at a height of 20 m

$$E_k(20\text{m}) = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times \quad \times v^2$$

$$v^2 =$$

$$v = \quad \text{m.s}^{-1}$$

2.8 the speed of the ball just before it hits the ground

$$E_{\text{mech}}(\text{bottom}) = \quad \text{J} = E_k(\text{bottom}) \quad \dots \text{remember } E_p(\text{bottom}) \text{ is } 0$$

$$E_k(\text{bottom}) = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times \quad \times v^2$$

$$v^2 =$$

$$v = \quad \text{m.s}^{-1}$$

Example 3

Assuming there is no air friction, if a 100 g ball is dropped from a 60 m high building, calculate:



3.1 the E_p of the ball at the top of the building

$$\begin{aligned} E_p(\text{top}) &= mgh \\ &= \quad \quad \times \quad \quad \times \\ &= \quad \quad \text{J} \end{aligned}$$

3.2 the E_{mech} at the top of the building

$$\begin{aligned} E_{\text{mech}}(\text{top}) &= E_p + E_k(\text{top}) \\ &= \quad + \quad \\ &= \quad \text{J} \end{aligned}$$

3.3 the E_p of the ball after it has fallen 15 m

$$\begin{aligned} E_p &= mgh \\ &= \quad \times \quad \times \\ &= \quad \text{J} \end{aligned}$$

3.4 the E_k of the ball after it has fallen 15 m

$$E_{\text{mech}}(\text{after 15m}) = \quad \text{J}$$

$$E_k(\text{after 15m}) = \quad \text{J}$$

Hint:
E_{mech} is constant the whole way down!

Hint: $E_{\text{mech}} = E_p + E_k$
(We know E_{mech} & E_p)

3.5 the speed of the ball after it has fallen 15 m

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

$$= \frac{1}{2} \times \quad \times v^2$$

$$v^2 =$$

$$v = \quad \text{m.s}^{-1}$$

3.6 the E_p of the ball at a height of 10 m

$$E_p (10\text{m}) = mgh$$

$$= \quad \times \quad \times$$

$$= \quad \text{J}$$

3.7 the velocity of the ball at a height of 10 m

$$E_{\text{mech}} (10\text{m}) = \quad \text{J}$$

$$E_k (10\text{m}) = \quad \text{J}$$

Remember
E_{mech} is
constant the
whole way
down!