National 5 Physics

Energy

ENERGY

Types of Energy

You should know from S1/S2 that there are several different types of energy:

- Gravitational Potential
- Elastic Potential
- Chemical Potential
- Electrical
- Light
- Sound
- Kinetic
- Nuclear

Watch it

https://youtu.be/mhIOylZMg6Q

https://youtu.be/NsDEgxmH8wI

You should also remember that all energy is measured in joules (J).

Law of the Conservation of Energy

The amount of energy in a system is **fixed**. Energy cannot be created or destroyed, only changed from one form into another. For instance a lift turns electrical energy into kinetic energy which is then turned into gravitational potential energy.

'Loss' of Energy

Even though energy cannot be destroyed it is normal to find that the energy put in is not the same as the energy out. For instance a lift uses a certain amount of electrical energy raising the lift. You can measure the electrical energy put in and calculate the gravitational potential energy of the lift. You would expect, given the law of the conservation of energy, that the two energies would be the same. However you would find that the energy put in is **more** than the energy. Where has this energy gone?

In real world situations no change of energy is perfect. There is always some sort of energy 'loss'. This is nearly always because some of the energy is changed into heat energy which is then transferred outside the system. For the example of the lift the lift's motor produced heat which then transfers to the room around the lift. Because this heat energy is almost impossible to recover we say that some energy has been 'lost'.

Summary

Energy is always conserved, but some can be lost, as heat, to the surroundings.

Kinetic Energy

Kinetic energy is the energy contained within a moving object. It is defined as being equal to one half multiplied by the mass of the object multiplied by the square of the object's speed. The formula for kinetic energy appears on the formula sheet and is given below:

$$E_k = \tfrac{1}{2} m v^2$$

Kinetic energy measured in joules (J)

Mass measured in kilograms (kg)

Speed measured in metres per second ($m\,s^{-1}$)

Example

A runner reaches full speed (10 $m\,s^{-1}$) during a 100 m race. If the runner has a mass of 75 kg, calculate the amount kinetic energy he has. In addition state the energy change that his body performs in reaching this speed.

Practice Problems

1. What is the kinetic energy of a 70 kg footballer running at 5 $m\,s^{-1}$?

2. What is the kinetic energy of a 90 kg rugby player running at 4 $m\,s^{-1}$?

3. An unknown mass has a kinetic energy of 400 J when it is travelling with a velocity of 20 $m\,s^{-1}$. What is the mass?

4. A lorry (mass 3000 kg) is moving at constant velocity. If it has a kinetic energy of 150,000 J — how fast is it travelling?

5. A car has a kinetic energy of 200 000 J when it is travelling at 20 $m\,s^{-1}$. What is the mass of the car?

6. A model race car of mass 10 kg is travelling along a circuit at a constant velocity. If it has a kinetic energy of 3125 J — how fast is it travelling?

Gravitational Potential Energy

Gravitational potential energy is a measure of how much extra energy an object has when it is raised up off the ground. It is equal to the mass of the object times the height is has been raised by times the gravitational field strength of Earth (which is 9.8 $\mathrm{N\,kg^{-1}}$). The formula appears on the formula sheet and is shown below:

Gravitational potential energy measured in joules (J)

Gravitational field strength measured in newtons per kilogram ($\mathrm{N\,kg^{-1}}$). On Earth g=9.8 $\mathrm{N\,kg^{-1}}$

$$E_p = mgh$$

Mass measured in kilograms (kg)

Height that the object has been raised by measured in metres (m)

Example

A woman of mass 60 kg climbs a set of stairs. There are 20 stairs each measuring 0.15 m in height. How much gravitational potential energy does she gain?

Practice Problems

1. A 6 kg box is raised through a height of 10 m. Calculate the gain in gravitational potential energy of the box.

2. A student of mass 50 kg climbs a set of stairs. Each step is 0.2 m high and there are 18 steps. Calculate the gravitational potential energy gained by the student.

3. How high must you raise a 50 kg mass before it has a potential energy of 100,000 J?

4. A crate has a potential energy of 2,000 J when it is 70 m above the ground. What is the mass of the crate?

5. How high must you raise a 1 kg mass before it has a potential energy of 20 J?

Work Done

Work is a type of **energy**. Other types of energy need to be converted into work to produce a force.

Work formula

Work done is defined as being equal to the force times the distance over which the force acts. It appears in the formula book and looks like this:

Force measured in newtons (N)

$$E_w = Fd$$

Work done measured in joules (J)

Distance measured in metres (m)

Practice problems

1. A car applies its brakes and comes to a halt in 30 m. If the car's brakes provide an average breaking force of 3,000 N, how much work did the brakes do?

2. If a block is pushed 2 m and required 14,000 J of work, how large was the force pushing the block?

3. An engine produces a force of 5,000 N and has done 8000 J of work moving a car. How far has the car travelled?

Calculating Vertical Displacement

A ball that is simply dropped from a certain height h will have a certain gravitational potential energy that is converted to kinetic energy. The ball will have the same amount of kinetic energy right before it hits the ground as it does gravitational potential energy before it is dropped.

$$E_p = E_k$$

$$mgh = \tfrac{1}{2}mv^2$$

(You may have seen these formulae already in the Electricity and Energy unit)

Here m is the mass of the object, h is the height of the object above ground level when dropped, v is the velocity of the object just before impact and g is the gravitational field strength. Note that m appears on both sides of this equation, which means we can cancel out the mass.

$$mgh = \tfrac{1}{2}mv^2$$

$$gh = \tfrac{1}{2}v^2$$

$$h = \frac{v^2}{2g}$$

This is another route to proving Galileo's conjecture that the mass of an object will not affect the rate at which it drops!

Calculations Using the Law of the Conservation of Energy

At National 5 you can be expected to notice that the law of conservation of energy can be used to solve problems. This means equating the different energy formulae. Below are all of the ones that can be equated at National 5:

$$E_w = Fd$$

$$E_p = mgh$$

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

$$E_h = cm\Delta T$$

$$E_h = ml$$

$$P = \frac{E}{t}$$

Example

Oranges hang from a branch of a tree. An orange has a mass of 200 g and is at a height of 7 m above the ground. The orange falls to the ground.

a) Calculate the gravitational potential energy it has when it is hanging from the tree.

b) Assuming that air resistance is negligible, what will be the kinetic energy of the orange just before it hits the ground?

c) How fast will the orange be travelling just before it hits the ground?

Another Example

A rock is thrown horizontally from a cliff 20 m above the surface of the sea. What is the speed of the rock just before it hits the sea?

Practice Problems

1. A ball of mass 0.5 kg is dropped from a tower which is 75 m high.

   a) Before the ball is dropped, how much gravitational potential energy does it have?

   b) Assuming all energy is transferred to kinetic energy, calculate the speed of the ball just before it reaches the ground.

2. A model rocket is fired straight up with an initial speed of 8 $m\,s^{-1}$, the rocket has a mass of 0.2 kg.

   a) Calculate the initial kinetic energy of the rocket.

   b) The mass of the rocket does not change. The rocket reaches its maximum height. What is the gravitational potential energy gained by the rocket?

   c) Use your answer from *b* to calculate the maximum height reached by the rocket.

3. A car is being driven along a road at 15 $m\,s^{-1}$. The total mass of the car and driver is 900 kg.

   a) Calculate the kinetic energy if the car and driver.

   b) The brakes are applied and the car is brought to rest outside a shop. Describe the energy change that has taken place.

   c) How much heat energy will be stored in the brakes when the car stops?

   d) About ten minutes later, the driver comes out of the shop and thinks he notices a problem with the brake disk and feels the disc. It feels cool. Where has the heat energy gone?

4. A meteor enters the Earth's atmosphere at 30,000 $m\,s^{-1}$. It has a mass of 880 kg and is made of a material with an specific heat capacity of 570 $J\,kg^{-1}\,°C^{-1}$. The material melts at 2200 °C.

   a) Calculate the kinetic energy of the meteor.

   b) What happens to the speed of the meteor as it hits the atmosphere? Explain why this happens.

   c) If all the kinetic energy becomes heat energy, and is used to change the temperature of the meteor, calculate the change in temperature of the meteor.

   d) Does the meteor hit the Earth? If not, explain why not.

5. A space capsule with a mass of 1440 kg re-enters the Earths atmosphere at 24,000 $m\,s^{-1}$. The capsule has an average specific heat capacity of 970 $J\,kg^{-1}\,°C^{-1}$.

   a) Calculate the kinetic energy of the capsule on re-entry.

   b) If all the kinetic energy is transferred to heat energy of the capsule, calculate the predicted final temperature of the capsule if there is no change of state.

6. A spacecraft has a mass of 875 kg, decelerates from 10,000 ms^{-1} to 500 ms^{-1} as it enters the atmosphere.

   a) Calculate the original kinetic energy of the spacecraft.

   b) Calculate the final kinetic energy of the spacecraft.

   c) If the spacecraft travels 1×10^5 km through the atmosphere as it comes into land, what is the average force due to air friction during this process?

Energy

You need to know:

	✓ ? ✘
That energy is conserved	
How to use the $E_k = 1/2\ mv^2$ formula	
How to use the $E_p = mgh$ formula	
How to recognise and solve a conservation of energy question involving any of the energy formulae	