- ***Candidates should be able to :***

  - *Define **WORK DONE** by a force.*

  - *Define the **JOULE.***

  - *Calculate the work done by a force using :*

    $W = Fx$ **and** $W = Fx\cos\theta$

  - *State the **PRINCIPLE OF CONSERVATION OF ENERGY.***

  - *Describe examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples.*

  - *Apply the idea that **work done = energy transferred** to solve problems.*

- ***ENERGY FORMS***

- ***ENERGY** is needed :*

  - *To make an object move.*
  - *To change the shape of an object.*
  - *To raise an object above the ground.*
  - *To raise the temperature of an object.*
  -

- ***ENERGY** may be defined as that which enables a body to do work.*

- *Although all energy can basically be described as being either **KINETIC** or **POTENTIAL** energy, we use different names to describe the energy forms which we encounter most frequently in everyday situations. These useful labels include :*

  - ***KINETIC ENERGY** - The energy possessed by a moving object.*

  - ***GRAVITATIONAL POTENTIAL ENERGY** - The energy stored (in the Earth-object system) when an object is raised to a higher level.*

  - ***ELASTIC POTENTIAL ENERGY** - The energy stored in springs or in any elastic material which is stretched or compressed.*

  - ***CHEMICAL ENERGY** - The energy stored in mixtures of chemicals or in chemical compounds. All fuels (coal, oil, gas) store chemical energy.*

  - ***ELECTRICAL ENERGY** - The energy transferred in electrical circuits by the motion of charge carriers such as electrons.*

  - ***RADIANT ENERGY** - The energy carried by all types of electromagnetic waves (i.e. γ-rays, x-rays, ultra-violet, visible light, infra-red, microwaves, and radio waves).*

  - ***INTERNAL ENERGY** - The energy possessed by a body due to the random distribution of the kinetic and potential energies of the molecules which make it up.*

  - ***THERMAL OR HEAT ENERGY** - The energy due to the Temperature of an object.*

  - ***SOUND ENERGY** - The energy produced by vibrating objects. (e.g. musical instruments, sounding loudspeaker etc ..).*

- ***ENERGY TRANSFORMATIONS***

- *Energy can be changed from one form into another (i.e. it can be **TRANSFORMED**).*

- *In any energy transformation, **the total amount of energy after the change = the total amount of energy before the change.***

  This is so because :

  ENERGY CANNOT BE CREATED OR DESTROYED, IT CAN ONLY BE TRANSFORMED.

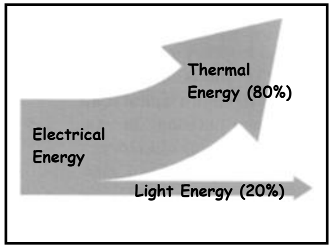
  *This is the **PRINCIPLE OF CONSERVATION OF ENERGY**.*

  *When we speak of energy being 'lost' or 'wasted', what we really mean is that some device or process has produced a form of energy that is not wanted (e.g. thermal energy caused by friction, sound energy etc..). This energy has not been 'lost' from the Universe, but we may regard it as being **dissipated** to the surroundings by whatever process has produced it.*

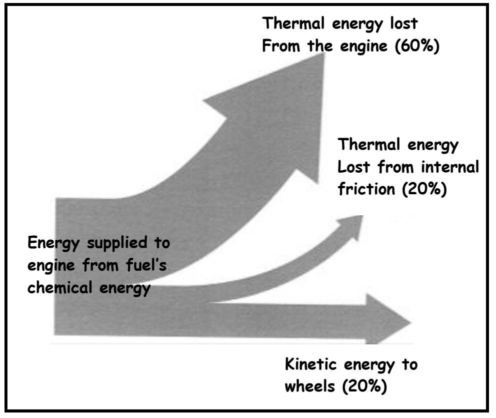
- *Energy arrow diagrams (called **SANKEY DIAGRAMS**) are schematic representations of energy transfer situations. In these diagrams the width of each segment of the arrow shows the proportion of the energy that is transformed into each form.*

SIMPLE ENERGY TRANSFORMATION EXAMPLES

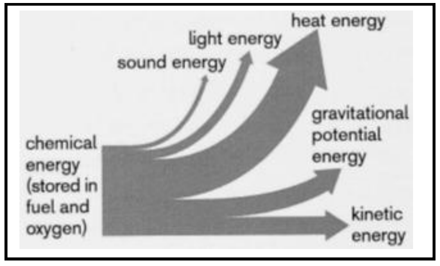
- *In a **Filament Bulb** only 20% of the electrical energy which powers the bulb is transformed into useful light energy. The remaining 80% is transformed into unwanted thermal energy.*



- *In a **Car Engine** the energy supplied to the engine is the chemical energy from the fuel and oxygen. 80% of this is transformed to unwanted thermal and sound energy and only 20% becomes useful kinetic energy to overcome air resistance.*



- *In a **Rocket Engine** the chemical energy in the fuel and oxygen is transformed to useful kinetic energy and gravitational potential energy as well as unwanted heat, light and sound energy.*



- ***ENERGY TRANSFER***

- *It should be noted that energy is __TRANSFORMED__ when it is changed from __one form into another__ whereas it is __TRANSFERRED__ __from one object to another, or from place to place.__*

- ***Energy can be transferred by :***

HEATING — *Energy transfer occurs as a result of a temperature difference between a hot object and its cooler surroundings.*

WORKING — *Energy transfer occurs as a result of a force doing work (e.g. lifting, pulling or pushing an object).*

WAVES — *Energy transfer occurs as a result of waves (e.g. light,IR, UV, etc) being propagated*

ELECTRICITY — *Energy transfer occurs as a result of electric charge flowing through components such as a resistor, filament bulb, motor etc.*

- ***WORK (W)***

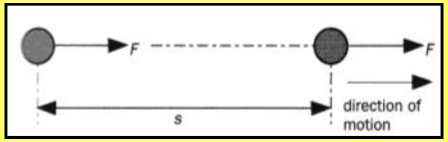
- ***WORK (W)** is said to be done when a force moves its point of application in the force direction.*

*This can increase the **kinetic energy** or the **potential energy** of an object.*

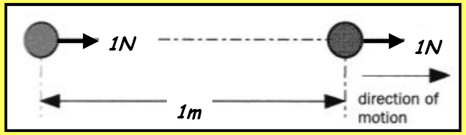
- ***WORK DONE = FORCE x DISTANCE MOVED IN THE FORCE DIRECTION***

$$W = F \times s$$

(J) (N) (m)



- ***1 JOULE (J)** is the work done when a force of **1 NEWTON (N)** moves its point of application a distance of **1 METRE (m)** in the force direction.*

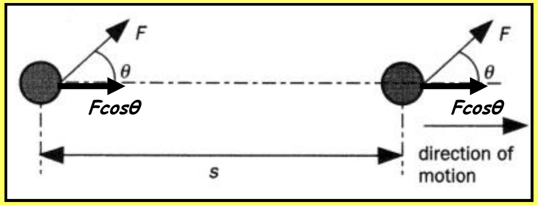


1 joule = 1 Newton x 1 metre

$$1\ J = 1\ N \times 1\ m$$

$$1\ J = 1\ Nm$$

If the force (F) acts at an angle (θ) to the direction of motion, we must multiply the component of (F) in the direction of motion (i.e. Fcosθ) by the distance moved in order to calculate the work done.



work done = force component in the direction of motion x distance moved in the direction of motion

$W = F\cos\theta \times s$

From which we have : $W = Fs\cos\theta$

(J) (N) (m)

NOTE

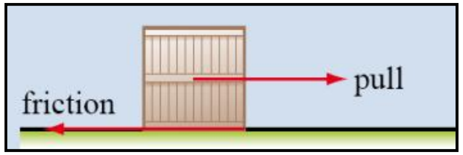
- If there is no movement, $s = 0$, so $W = F \times s = 0$. Therefore, **NO WORK IS DONE IF THE FORCE DOES NOT MOVE**.
- If F acts at right angles to the direction of motion, $\theta = 90°$, so $\cos\theta = \cos 90° = 0$ and $W = Fs\cos\theta = 0$. Therefore, **NO WORK IS DONE IF THE FORCE ACTS AT RIGHT ANGLES TO THE DIRECTION OF MOTION**.
- **WORK DONE IS A SCALAR QUANTITY**.

WORK DONE AND ENERGY TRANSFERRED

- When work is done, energy is transferred.

WORK DONE = ENERGY TRANSFERRED

- In the solution of many problems we make the assumption that **all** the work done on an object is transferred as kinetic or potential energy of the object (i.e. that none of the work done is wasted as heat or sound). In practice, some of the work done is always transferred as unwanted heat and sound energy.



For example, if a crate is pulled along the ground as shown opposite, some of the work done will be used to overcome the frictional force which opposes the motion. The crate and the ground will heat up and some sound will also be produced. So, although in simple calculations we may assume that the work done on the crate is totally transferred to kinetic energy, the reality is that :

work done on crate = kinetic energy gained by crate + (heat energy + sound energy)

HAS WORK BEEN DONE ?

In order to decide whether or not work has been done in any given situation, we need to ask the following questions :

- **Has the force moved its point of application ?**

Work will have been done if the answer is yes. So **if the force does not move or if the force acts at right angles to the direction of motion, no work is done.**

- ***Has energy been transferred by the force ?***

*Work will have been done if the answer is yes. So **the object on which the work is done will gain energy** (In most of the cases we will consider the energy gained is kinetic or potential).*

- **HOMEWORK QUESTIONS**

1 In each of the following examples, ***state*** and ***explain*** whether or not any work is done by the force mentioned.

(a) Pulling a child in a pushchair along the sand on a beach.

(b) Pushing a very heavy off-road vehicle, but being unable to get it to move.

(c) A boulder falls off a cliff under the force of gravity.

(d) The force of gravity keeps the Moon orbiting the Earth at constant speed.

(e) An object attached to a light string is whirled in a horizontal circle at constant speed and it is the tension in the string which provides the force needed for this motion.

(f) A weight-lifter lifts a heavily laden barbell from the ground to a point above his head.

(g) The same weight-lifter holds the weights at the same height above the ground.

2 (a) Name the ***form of energy*** possessed by :

(i) A bullet fired out of a gun,
(ii) A stretched or compressed spring,
(ii) A car battery,
(iv) An object placed at some height above the ground.

(b) Write an equation to represent the ***transformation*** of chemical energy stored in petrol or diesel when a car is accelerating from rest.

(c) (i) Name the most common form of ***waste energy.***
(ii) Name ***two*** other forms in which energy is often wasted.

(d) (i) What is the name given to the process by which ***energy may be transferred by a force.***
(ii) Name ***two*** other ways in which energy may be transferred.

(e) A hairdryer is connected to the mains electricity supply. It is being used to dry a person's wet hair by blowing hot air onto it.

(i) What are the two ***wanted*** forms of energy which the hairdryer is producing ?
(ii) What form of ***waste*** energy is produced ?

3 Negotiating the ***Mediterranean Steps*** on the Eastern slopes of the ***Rock of Gibraltar*** involves climbing a total of ***456*** steps of average height ***32 cm.*** Calculate the ***work done against the force of gravity*** by a man of mass ***96 kg*** when he climbs all these steps.

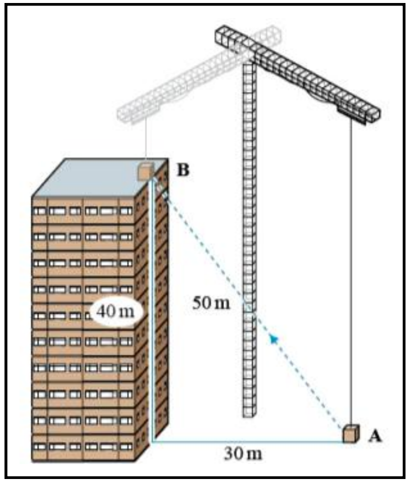
(Take the ***gravitational field strength, g*** as ***9.81 N kg***$^{-1}$).

4 A boulder of mass ***1450 kg*** is dislodged and falls from the top of a ***120 m*** high cliff.

(a) Calculate the ***work done by the force of gravity*** in bringing the boulder to the base of the cliff (Take $g = 9.81\ N\ kg^{-1}$).

(b) How much ***kinetic energy*** is theoretically transferred to the boulder by its fall ? Why is the kinetic energy transferred to the boulder ***less than this*** in practice ?

5 The crane shown in the diagram opposite lifts a ***2550 N*** load to the top of the building from ***A to B.***



(a) Given the distances as shown on the diagram, calculate the ***work done*** by the crane.

(b) What is the ***magnitude*** and ***form*** of the energy which is transferred to the load ?

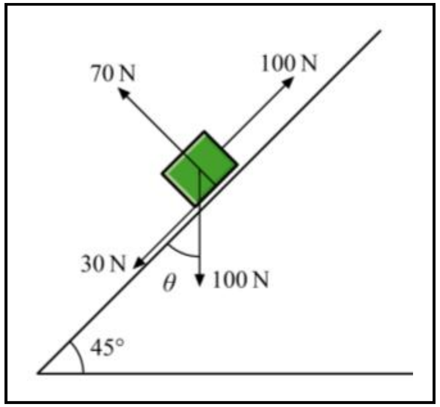
6 Calculate the ***energy transferred*** by a force of ***25 N*** when it moves an object by a distance of ***5.5 m*** :

(a) In ***the direction of the force.***

(b) In ***a direction at 30° to the force direction.***

(c) In ***a direction at 90° to the force direction.***

7 The diagram opposite shows the forces acting on a box as it is being pulled along a plane which is inclined at ***45°*** to the horizontal.



Calculate the ***work done*** by each of the forces if the box moves through a distance of ***0.50 m*** upwards along the plane.

8 A pulley system is used to lift ***25 kg*** stone blocks from the ground to the top of a ***36 m*** high building.

(a) Calculate the amount of ***work done*** by the pulley system in lifting each block (Take $g = 9.81\ N\ kg^{-1}$).

(b) During the lifting of a single stone block, 1.48×10^4 ***J*** of energy is supplied to the pulley system. How much of this energy is wasted and in what form or forms ?

9 A car with its passengers and luggage has a total weight of ***14.6 kN.*** The car travels a distance of ***1.2 km*** up a hill having a gradient of ***1 in 10*** (i.e. for every ***10 m*** it travels along the slope, the car rises ***1 m*** vertically).

Calculate the ***work done against gravity*** by the forward thrust provided by the car's engine.