Work, Energy and Power

Energy

We already know that it appears in a number of different forms and may be transformed from one form to another. But what is energy? **Energy is the ability to do work**.

We can say that the work done is equal to the energy transferred

Work done = energy transferred $\boxed{W = E}$

Work Done

In Physics we say that work is done when a force moves through a distance and established the equation

Work Done = Force x Distance moved in the direction of the force $\boxed{W = Fs}$

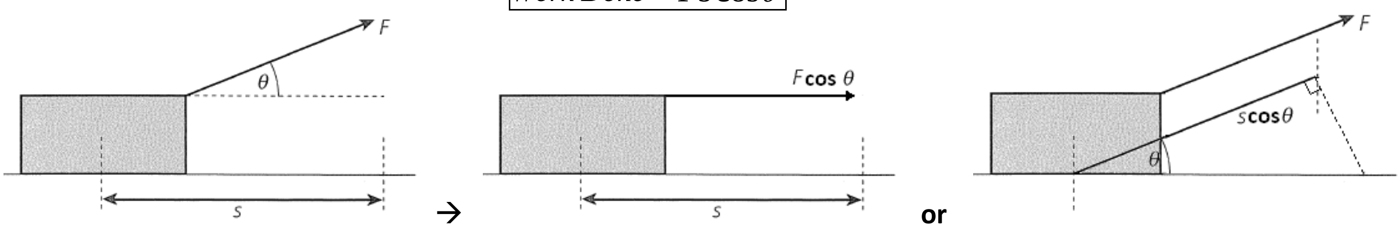
Work Done is measured in Joules, J
Force is measured in Newtons, N
Distance is measured in metres, m

The distance moved is not always in the direction of the force. In the diagram we can see that the block moves in a direction that is θ away from the 'line of action' of the force. To calculate the work done we must calculate the distance we move in the direction of the force or the size of the force in the direction of the distance moved. Both of these are calculated by resolving into horizontal and vertical components.

Work Done = Force x Distance moved in the direction of the force

Work Done = Size of Force in the direction of movement x Distance moved

$$\boxed{\text{Work Done} = Fs\cos\theta}$$



Power

Power is a measure of how quickly something can transfer energy. Power is linked to energy by the equation:

$$\boxed{Power = \frac{Energy Transferred}{time taken}} \quad \boxed{P = \frac{\Delta E}{\Delta t}}$$

Power is measured in Watts, W
Energy is measured in Joules, J
Time is measured in seconds, s

But Work Done = Energy Transferred so we can say that power is a measure of how quickly work can be done.

$$\boxed{Power = \frac{WorkDone}{timetaken}} \quad \boxed{P = \frac{\Delta W}{\Delta t}}$$

Now that we can calculate Work Done we can derive another equation for calculating power:

We can substitute $W = Fs$ into $P = \frac{W}{t}$ to become $P = \frac{Fs}{t}$ this can be separated into

$P = F\frac{s}{t}$.

$\frac{s}{t} = v$ so we can write $\boxed{P = Fv}$

Velocity is measured in metres per second, m/s or ms^{-1}

Efficiency

We already know that the efficiency of a device is a measure of how much of the energy we put in is wasted.

Efficiency = $\frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}$ this will give us a number less than 1

Useful energy means the energy transferred for a purpose, the energy transferred into the desired form.

Since power is calculated from energy we can express efficiency as:

Efficiency = $\frac{\text{useful output power of the device}}{\text{input power to the device}}$ again this will give us a number less than 1

To calculate the efficiency as a percentage use the following:

percentage efficiency = efficiency x 100%

Energy Transformations

We already know that energy cannot be created or destroyed, only transformed from one type to another and transferred from one thing to another. Eg a speaker transforms electrical energy to sound energy with the energy itself is being transferred to the surroundings.

An isolated (or closed) system means an energy transformation is occurring where none of the energy is lost to the surroundings. In reality all transformations/transfers are not isolated, and all of them waste energy to the surroundings.

Kinetic Energy

Kinetic energy is the energy a moving object has. Let us consider a car that accelerates from being stationary (u=0) to travelling at a velocity v when a force, F, is applied.

The time it takes to reach this velocity is give by $v = u + at$ → $v = at$ → $t = \frac{v}{a}$

The distance moved in this time is given by $s = \frac{1}{2}(u+v)t$ → $s = \frac{1}{2}(v)t$ → $s = \frac{1}{2}(v)\frac{v}{a}$ →

$s = \frac{1}{2}\frac{v^2}{a}$

Energy transferred = Work Done, Work Done = Force x distance moved and Force = mass x acceleration

$E = W$ → $E = Fs$ → $E = mas$ → $E = ma\frac{1}{2}\frac{v^2}{a}$ $\boxed{E_K = \frac{1}{2}mv^2}$

Velocity is measured in metres per second, m/s
Mass is measured in kilograms, kg
Kinetic Energy is measured in Joules, J

Gravitational Potential Energy

This type of potential (stored) energy is due to the position of an object. If an object of mass m is lifted at a constant speed by a height of h we can say that the acceleration is zero. Since *F=ma* we can also say that the overall force is zero, this means that the lifting force is equal to the weight of the object → $F=mg$

We can now calculate the work done in lifting the object through a height, h.

$$WD = Fs \rightarrow WD = (mg)h \rightarrow WD = mgh$$

Since work done = energy transferred

$$\Delta E_P = mg\Delta h$$

Height is a measure of distance which is measured in metres, m
Gravitational Potential Energy is measured in Joules, J

Work Done against….

In many situations gravitational potential energy is converted into kinetic energy, or vice versa. Some everyday examples of this are:

Swings and pendulums If we pull a pendulum back we give it GPE, when it is released it falls, losing its GPE but speeding up and gaining KE. When it passes the lowest point of the swing it begins to rise (gaining GPE) and slow down (losing KE).

Bouncing or throwing a ball Holding a ball in the air gives it GPE, when we release this it transforms this into KE. As it rises it loses KE and gains GPE.

Slides and ramps A ball at the top of a slide will have GPE. When it reaches the bottom of the slide it has lost all its GPE, but gained KE.

In each of these cases it appears as though we have lost energy. The pendulum doesn't swing back to its original height and the ball never bounces to the height it was released from. This is because work is being done against resistive forces.

The swing has to overcome air resistance whilst moving and the friction from the top support.

The ball transforms some energy into sound and overcoming the air resistance.

Travelling down a slide transforms energy into heat due to friction and air resistance

The *total* energy before a transformation = The *total* energy after a transformation