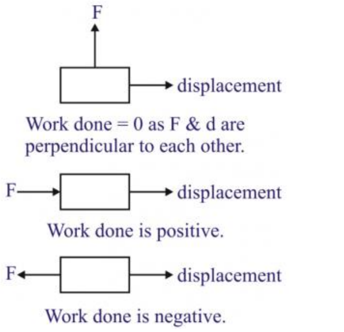
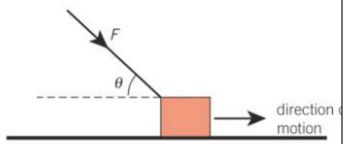
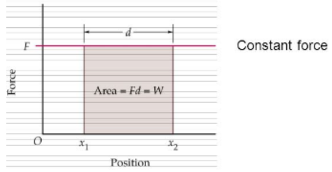
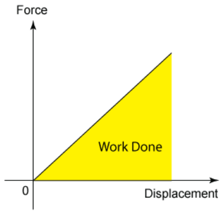
A Level Physics Knowledge Organiser

Work, energy and power

5

1. Work done and energy

Work done (in everyday life)	Any kind of physical or mental activity.
Work done (in physics)	The product of force and the distance moved in the direction of the force, measured in joules, J. Work done = force x distance moved in the direction of the force W = F x W – work done (J) F – force (N) x – distance (m) 
1 Joule	1 J is the work done when a force of 1 N moves its point of application 1 m in the direction of the force.
Work done and energy	Work done = energy transferred
Work done at an angle to motion	 work done $W = (F\cos\theta) \times x$ $W = Fx\cos\theta$

Force – displacement graph	The work done by a force can be found from the area between the force curve and the x-axis.  

2. Conservation of energy

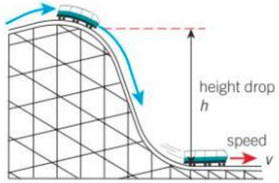
Principle of conservation of energy	The total energy of a closed system remains constant – energy cannot be created nor can it be destroyed.
Energy	The capacity for doing work, measured in joules, J.
Forms of energy	
Kinetic energy	Energy due to motion of an object with mass (e.g., moving car, moving atoms).
Gravitational potential energy	Energy of an object due to its position in a gravitational field (e.g., child at the top of a slide, water held in clouds).
Chemical energy	Energy contained within the chemical bonds between atoms – it can be released when the atoms are rearranged (e.g., energy stored within a chemical cell, energy stored in petrol and released when it is burnt).
Elastic potential energy	Energy stored in an object as a result of reversible change in its shape (e.g., a stretched guitar string, a squashed spring).
Electrical potential energy	Energy of electrical charges due to their position in an electric field (e.g., electrical charges on a thundercloud, static charge on a charged balloon).
Nuclear energy	Energy within the nuclei of atoms – it can be released when the particles within the nucleus are rearranged (e.g., energy from fusion processes in the Sun, energy from the nuclear fission reactors).
Radiant (or electromagnetic) energy	Energy associated with all electromagnetic waves, stored within the oscillating electric and magnetic fields (e.g., energy from the hot Sun, energy from an LED).
Sound energy	Energy of mechanical waves due to the movement of atoms (e.g., energy emitted when you clap, output energy from your headphones).
Internal (heat or thermal) energy	The sum of the random potential and kinetic energies of atoms in a system (e.g., a hot cup of tea has more thermal energy than a cold one).
Energy can be transferred	
Mechanically	By the action of a force.
electrically	By an electrical current.
By radiation	By light waves or sound waves.
By heating	By conduction, convection or radiation.

3. Kinetic energy and gravitational potential energy

Kinetic energy – linear motion	Energy due to motion of an object with mass. $E_k = \frac{1}{2}mv^2$ E_k or KE – kinetic energy (J) m – mass (kg) v – speed (m s^{-1})
Gravitational potential energy	Energy of an object due to its position in a gravitational field. The equation can be applied for the uniform gravitational field. E_p = m g h E_p or GPE – gravitational potential energy (J) m – mass (kg) g – acceleration of free fall (m s^{-2}) h – height (m) Things fall without any extra energy being supplied, so GPE is dissipated.
Gained GPE	When an object gets higher.
Lost GPE	When an object gets lower.
The origin of the equation for GPE	
$E_p = W$ = force × distance moved in the direction of force $E_p = (mg) \times h$	$E_p = mgh$
Total mechanical energy	The sum of the kinetic energy and the potential energy of the system at any moment. In a closed system, total mechanical energy is conserved.

Energy exchange

KE and GPE can be exchanged.
For example:



- The roller coaster is stationary on height h, and GPE is maximum.
- When roller coaster starts to move down, GPE decreases (height decreases) and at the same time KE increases because the velocity increases from 0.
- At the bottom, GPE is completely exchanged into KE (the height is equal to zero, and velocity is maximum).
- The total energy is conserved.

Therefore

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

v – final speed of the object
h – initial height of the object
Finally

$$gh = \frac{1}{2}v^2 \qquad v^2 = 2gh$$

$$v = \sqrt{2gh}$$

The equation above is only valid if there are no resistive forces involved.

4. Power and efficiency

Power

The rate of work done, measured in watts, W.
An equation is

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

P – power (W)
W – work done (J)
t – time (s)

Power

The rate of energy transfer, because work done is equal to energy transfer.

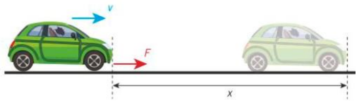
1 watt

1 W is equal to one joule per second.

1 W = 1 J s^{-1}

Constant force for applied for constant speed

Example:



- A car traveling on a level road at constant speed.
- The net force on the car is zero.
- The rate of work done by the forward force provided by the car in equal to the rate of work done against the frictional forces acting on a car.
- A constant force *F* moves the car a distance *x* in a time *t*.
- Work done by the force is

W = F x

$$P = \frac{W}{t} = \frac{Fx}{t}$$

The speed v of the car is x/t.
Therefore

P = F v

Efficiency

The ratio of useful output energy to total input energy, is often expressed as a percentage.
- The processes and machines turn all their energy into useful and wasted output energy, not just into useful output energy.

$$efficiency = \frac{useful\ output\ energy}{total\ input\ energy} \times 100\%$$

- The greater the efficiency, the greater the percentage of input energy converted.
- Efficiency can never be more than 1, or 100 percent, because it would break the law of conservation of energy if the amount of energy output was more than the energy put in.

Typical efficiencies

System	filament lamp	muscles	petrol engine	solar cell
Typical efficiency /%	5	20	20	25

	LED	diesel engine	wind-generator	electric heater
	35	35	40	~ 100