Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Power

Going past measuring and describing energy transfers, we can consider how fast the energy transfer is (or, how fast the work is done). The rate (speed) of energy transfer is the **power**. The top two equations below show this.

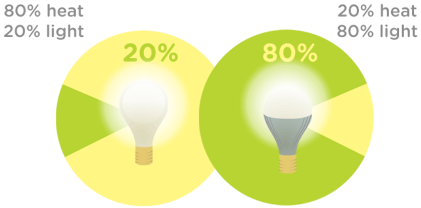
Two things might transfer the same amount of energy (do the same amount of work), but if one does it faster than the other, it has a higher power. For instance, if two people of the same mass run the same distance, they transferred the same amount of energy or do the same amount of work. However, if one of them completes it faster than the other, they had a higher power. (The 't' in the equation would be smaller, leading to a larger value for 'P'.)

Efficiency of Energy Transfers

As you know, energy cannot be created or destroyed, just transferred. It is often useful to measure how much energy is transferred in the way we want, and how much is dissipated. This measure is called **efficiency** (see equations). Since there is **always** some wasted energy, efficiency must always be less than 1, or less than 100% if you convert the efficiency to a percentage.

To improve efficiency, we reduce the energy transferred in ways that are not useful (i.e. reduce the wasted energy). In a simple example, the light bulb on the left wastes 80% (efficiency = 0.2 or 20%) of the input energy as heat energy, but the one on the right only wastes 20% (efficiency = 0.8 or 80%).

Similarly, the methods such as insulation or lubrication improve efficiency, since they reduce the energy transfer to wasted forms of energy.



Key Terms	Definitions
Power	Power is the **rate** of energy transfer – also known as the rate at which work is done. (Remember, energy transferred is the same as work done.) Since it is a rate, like speed, power is calculated by dividing by time (see equations).
Watt (W)	The watt is the unit for power. One watt is one joule transferred in one second – or 1 J/s (1 joule per second).
Efficiency	The measure of how much of the stored energy in a system is transferred usefully. More efficient devices transfer more energy usefully, which is the same as saying they waste less energy.

Equation	Meanings of terms in equation and units
$P = \frac{E}{t}$ *	*P = power (watts, W)* *E = energy transferred (joules, J)* *t = time (s)*
$P = \frac{W}{t}$ *	*P = power (watts, W)* *W = work done (J)* *t = time (s)*
* $efficiency = \frac{\text{useful energy output}}{total\ energy\ input}$	*Efficiency doesn't have a unit. You can convert the efficiency (which will be a decimal) to a percentage by multiplying by 100.*
* $efficiency = \frac{\text{useful power output}}{total\ power\ input}$	

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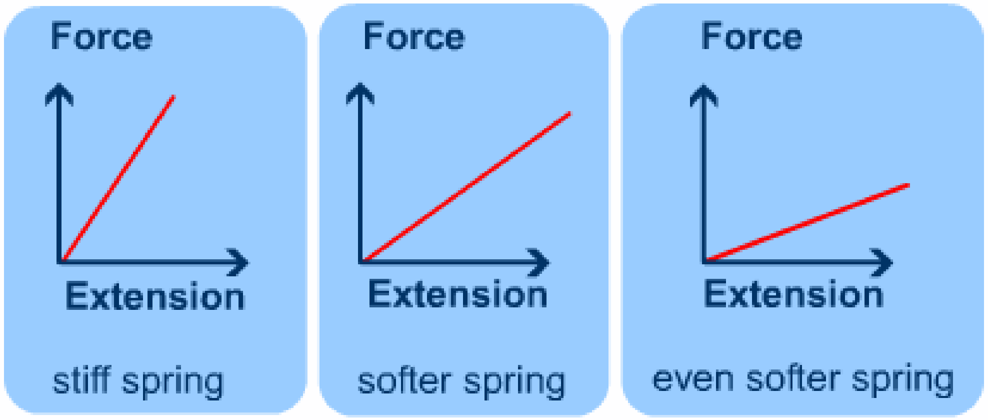
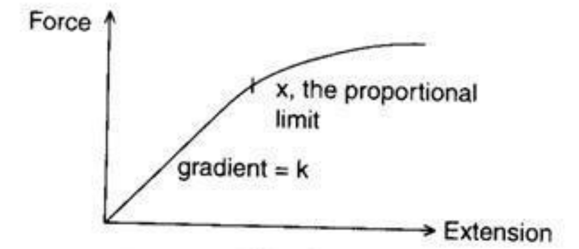


Force and Extension/Compression

The extension of an elastic object, like a spring, is directly proportional to the force applied to it, provided the limit of proportionality of the spring is not exceeded. This also works with the compression of an object – you can use the equations below too, '*e*' just means the amount of compression. The **spring constant** measures how much extension you get for your force. A large spring constant means it won't stretch far compared to a spring with a small spring constant, if the same force is applied (see examples above). The spring constant can be calculated from the gradient of a graph of force against extension.

When force is applied to a spring, it moves a distance, so **work is done.** In other words, energy is transferred. The energy gets stored in the spring (or elastic object) as **elastic potential energy *(E_e)***. The amount of elastic potential energy is calculated by the equation shown on the right.



On graphs showing force against extension, you can see when the limit of proportionality is reached by looking at where the graph starts to curve. (Labelled x on this example)

Key Terms	**Definitions**
Elastic	Describes objects that return to their original shape after being deformed by a force, once the force is removed
Elastic deformation	Deformation (bending, stretching or compressing an object) is elastic if the object returns to its original shape once the force is removed
Deformation	Bending, stretching or compressing an object
Extension	The change in length of an object such as a spring. Subtract length when NO force is applied from the length when a force is applied.
Directly proportional	This term describes a type of relationship between two variables. The two variables are directly proportional if, for every increase of one variable by one unit, the other increases by the same amount. It is shown by a straight line on a graph that goes through the origin.
Limit of proportionality	The limit of a directly proportional relationship. It can be shown on a graph if the line is straight to being with (indicating a directly proportional relationship) then curves.
Linear relationship	Simply, a relationship between two variables that is graphed as a straight line.
Non-linear relationship	A relationship between two variables that is shown with a curved line on a graph.
Gradient	The gradient of a graph is how steep it is. Calculate gradient by dividing the change in the variable on the y-axis by the change in the variable on the x-axis.

Equation	**Meanings of terms in equation**
$F = k\,e$ *	*F = force (newtons, N)* *k = spring constant (newtons per metre, N/m)* *e = extension (metres, m)*
$E_e = 0.5k\,e^2$	*E_e = elastic potential energy (joules, J)* *k = spring constant (newtons per metre, N/m)* *e = extension (metres, m) – this is **squared** in this equation*

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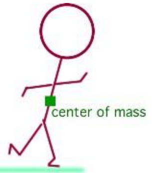
Weight

Weight is often mistaken for **mass**; for instance, when people say they are losing weight, they really mean they are losing mass. As a result, their weight will also drop (see equation), but really it is their mass they seek to change. Mass measures how much material there is (in kg), whereas weight measures the **force** acting on an object due to a **gravitational field**.

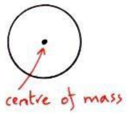
Looking at the equation, you can see that a person with a mass of 65 kg will have a weight of 65 x 10 = 650 N. You can also see that a mass of 100 g (=0.1 kg) has a weight of 1 N on Earth.

As the equation shows, weight and mass are **directly proportional**. We can show this like: $W \propto m$, using the symbol for a directly proportional relationship. On Earth, as mass increases by one unit, weight increases by ten units (as *g* = 10 N/kg).



Centre of Mass

When drawing force diagrams and performing calculations, it is useful to show the weight (or other forces) acting on just a single point on the object. This is the exact centre of a symmetrical object (it will be more complicated for an asymmetrical object), and is called the **centre of mass**. Think of the centre of mass as the point where we consider weight to act: as a result, force arrows should start on the centre of mass.



Measuring Weight

Weight can be determined by calculation using the equation, or directly measured using a **calibrated** (adjusted so the scale is right) spring balance – a newtonmeter. This can be mechanical or digital – a digital newtonmeter will likely have higher **resolution** (detects smaller differences in weight).

Key Terms	Definitions
Weight	Weight is different to mass. Weight is a **force** (hence, it is a vector quantity), caused by gravity acting on a mass. Since it is a force, it is measured in newtons.
Mass	Mass measures the amount of material in an object, and is measured in kilograms (kg). The weight of an object depends on the mass, but mass does not depend on weight. Mass is a scalar quantity.
Gravitational field strength	Simply, the measure of how strong the gravitational field of a large object is. For instance, the gravitational field strength on Earth is about 10 N/kg. This means that a weight of 10 N acts on each kg of mass on Earth.
Centre of mass	The point at which the weight of an object is considered to act – the 'middle' of the object's mass.
Newtonmeter	A device to measure weight. It simply consists of a spring and a calibrated scale.

Equation	Meanings of terms in equation
$W = m\,g$ *	*W = weight (newtons, N)* *m = mass (kilograms, kg)* *g = gravitational field strength (newtons per kilogram, N/kg) – on Earth, this is about 10 N/kg*
$E_p = m\,g\,h$	E_p = *Gravitational Potential Energy (Joules, J)* *m = mass (Kilograms, kg)* *g = gravitational field strength (newtons per kilogram, N/kg) – on Earth, this is about 10 N/kg* *h = height (meters, m)*

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Power

You should recall that power is **the rate of energy transfer**, or the rate at which work is done. In electrical components, including any electrical appliance, the power relates to the potential difference across the component and the current through it. If either p.d. or current increases, the power increases. In other words, the rate of energy transfer increases. This should be clear from the first equation.

The second equation also finds the power. The equation comes from substituting in $V = IR$. The second equation is useful if you don't know the p.d. across a component.

Energy transfers in electrical appliances

The whole point of electrical appliances is to transfer energy. The electrical potential energy from the supply is transferred to something useful – such as light and sound in your TV. The other way of saying this is that **work is done** when **charge flows** in a circuit.

Some examples of energy transfers in electrical appliances:
- In your mobile phone, electrical potential energy from the dc supply (the battery) is transferred to light, sound and thermal energy. This means the energy from the battery is **dissipated** to the surroundings.
- A washing machine transfers electrical potential energy from the ac mains supply to kinetic energy in the electric motor (that's why it spins), along with heat. Eventually, all the energy of the input is dissipated to the surroundings.
- An electric heater transfers the electrical potential energy of the supply to thermal energy. The energy stored in the supply ends up stored in the air, the walls, the floor and so on around the heater: stored in the heat of the materials.

The amount of energy transferred by an appliance depends on the **power** of the appliance and the **time** it is switched on for. To find the amount of energy transferred, simply multiply the power of the appliance by the time it is on for (see third equation).

Furthermore, since p.d. is a measure of how much work is done per coulomb of charge, you can find out how much work is done (aka energy transferred) by a circuit by multiplying the charge flow by the p.d. (see fourth equation).

Key Terms	Definitions
Power	The rate of energy transfer. In electrical components, the power is found by multiplying p.d. by current.
Work	Transfer of energy.
Appliance	Any device that transfers electrical energy to other forms. The supply of electrical energy can be a cell, battery, or the mains ac supply.

Equation	Meanings of terms in equation
$P = V I$ *	*P = power (watts, W)* *V = potential difference (volts, V)* *I = current (amps, A)*
$P = I^2 R$ *	*P = power (watts, W)* *I = current (amps, A)* *R = resistance (ohms, Ω)*
$E = P t$ *	*E = energy transferred (joules, J)* *P = power (watts, W)* *t = time (seconds, s)*
$E = Q V$ *	*E = energy transferred (joules, J)* *Q = charge flow (coulombs, C)* *V = potential difference (volts, V)*

High power, low power

The power of an appliance determines how much energy is transfers in a given length of time. If an appliance has a high power (e.g. a washing machine), it transfers lots of energy in a given time. If it has a low power (e.g. a lamp), it doesn't transfer much energy in a given time, in comparison.

The other way of looking at it is how long the appliance takes to transfer a given amount of energy, e.g. 1000 J. A washing machine will transfer the energy in a very short length of time, whereas a lamp will take much longer to transfer this energy.