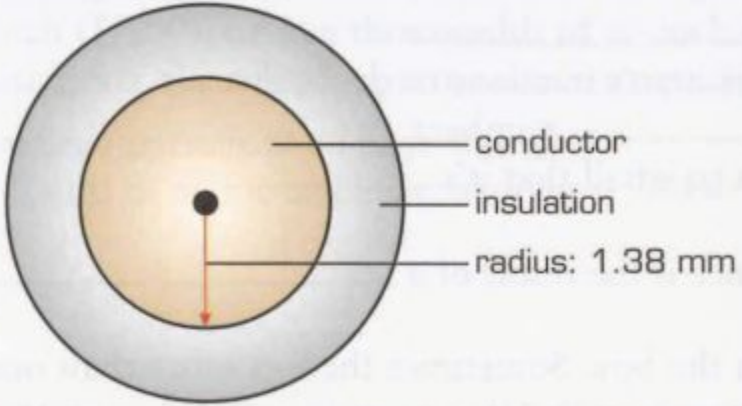
Area, size and mass

A Area

The textbook extract below looks at different aspects of **area**.

Dimensions of wires and cables

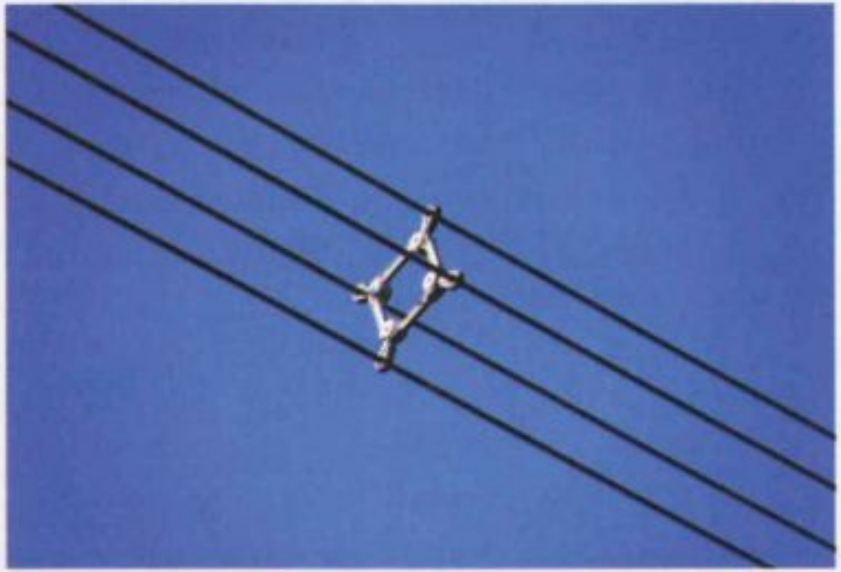
The sizes of electrical wires are specified by a number which gives an area in **square millimetres**. For example, in a home, a 6 mm^2 wire may be specified to supply an electric oven in a kitchen. This number gives the **cross-sectional area** of the conductor. Increasing the cross-sectional area allows the conductor to carry more current safely, without overheating.



Cross-sectional area = $\pi r^2 = 3.14 \times 1.38^2 = 6$

Cross-section of 6 mm^2 wire

In high-voltage power lines, it is not only the cross-sectional area of conductors that is important, but also their **surface area** – the amount of surface that is in contact with the air, to allow cooling. Therefore, instead of using single cables with large sections for each conductor, power lines often use groups of two, three or four **small-section** cables, to give more surface area than a single, **large-section** cable.



B Weight, mass, volume and density

In everyday language, the term **weight** means how heavy things are (how much they **weigh**), and **grams** and **kilograms** are used as units of weight. But in physics and in engineering, grams and kilograms are units of **mass**. Whether an object is on earth – where it is subjected to **gravity** (the pull of the earth) – or floating **weightless** in space, its mass is always the same. The mass of an object depends on:

- the **volume** of the object, measured in **cubic metres** (m^3) – as an object's volume increases, its mass increases
- the **density** of the object, measured in **kilograms per cubic metre** (kg/m^3) – as density increases, mass **per unit of volume** increases.

The mass of an object is the object's volume multiplied by its density. The weight of an object is the force exerted on the object's mass by gravity.

Some materials are very **dense**, and therefore very heavy. An example is lead (Pb), which has a density of 11,340 kg/m^3. Other materials, such as expanded polystyrene (which can have a density as low as 10 kg/m^3), are very **lightweight**.

9.1 The component below is made of mild steel. It has a radius of 40 mm and it is 1,200 mm long. Complete the calculations using the words in the box. Look at A and B opposite to help you.

cross-sectional area	density	mass	surface area	volume

(1) .... of mild steel: 7,850 kg/m³

(2).............................. : $\pi r^2 = 3.14 \times 40^2 = 5\ 024\ mm^2 = 0.005024\ m^2$

(3) .... : $0.005024\ m^2 \times 1.2\ m = 0.0060288\ m^3$

(4) .... : $0.0060288\ m^3 \times 7{,}850\ kg/m^3 = 47.32608\ kg$

Circumference: $2\pi r = 3.14 \times 40\ mm = 251\ mm = 0.251\ m$

Total (5) .... to be painted: $0.251\ m \times 1.2\ m + 0.005\ m^2 + 0.005\ m^2 = 0.311\ m^2$

9.2 Now write the whole words for the unit abbreviations in the calculation in 9.1 above. Look at A and B opposite to help you. The first one has been done for you.

1 m	*metres*	4 m^2	7 kg/m^3	
2 mm		5 m^3		
3 mm^2		6 kg		

9.3 Complete the extract from an article about satellite design using the words in the box. Look at A and B opposite to help you.

cubic	gravity	lightweight	mass	square	weigh	weightless

Satellites need to be designed to cope with two very different phases: deployment (the journey into space by rocket) and operation (working in space).

For the first phase, engineers are faced with the problem that every (1) .... metre of volume taken up within the rocket will add millions of dollars to its ticket into space. And each extra gram of (2) .... added to the craft will increase the fuel needed to propel it upwards against the pull of (3) .... That extra fuel, in turn, will (4) .... a little more, further adding to the total weight of the craft. With the cost of kilograms so high, the satellite must therefore be as (5) .... as possible.

In the second phase, with the orbiting satellite now (6) .... , its mass is practically irrelevant. As for the amount of space occupied, the situation is completely reversed. The satellite's solar panels, which transform sunlight into battery power, must unfold to cover as wide an area as possible – opening out to cover an area of several (7) .... metres – in order to maximize their exposure to the sun.

Measurable parameters

A Supply, demand and capacity

The article below is from the technology section of a business magazine.

Technology

Calculating the **capacity** of an electricity grid – the amount of energy it needs to **supply** to users – might seem simple. Just add up the power supplied over a given **period** of time to give the total amount **consumed** by users. Then, divide the **cumulative** amount of power used during the whole period by the number of hours in the period. The result is an **average** level of **consumption** per hour. But there's one problem with this method – and it's a major one.

The **rate** of power consumption – the amount that's being consumed at a particular moment – is not **constant**. In other words, consumption does not stay at the same level all the time. So electricity **supply** requirements cannot simply be **averaged out** over time. People use more power at certain times of day, and less at other times, which means that **demand** for power **fluctuates** significantly. Generally, it rises to a maximum in the evening (**peak** demand is at evening mealtimes), and falls to its lowest levels during the night. These **fluctuations** are so big that at **peak times** consumption can be twice as high as it is during **off-peak times**. Clearly, the grid needs to have sufficient capacity to **meet demand** when consumption **peaks**. But since each peak is brief, the grid will only **run to capacity** – at or close to its maximum capability – for a few moments each day. This means, most of the time, it has significant **spare capacity**.

B Input, output and efficiency

Power lines and transformers are relatively **inefficient**, wasting energy – mainly by giving off heat. As a result, there is a difference between **input** – the amount of energy put into the grid by power stations, and **output** – the amount used by consumers. On a typical grid, the difference between input and output is about 7% – there is a 7% energy **loss**. But if electricity is generated at the place where it's consumed, and not transmitted through long-distance power lines, this loss can be avoided. Consequently, locally produced electricity is more **efficient** than grid-supplied power, as there is a **gain** in **efficiency** of around 7%.

Photovoltaic solar panels

One way to produce power locally is with photovoltaics (PVs) – often called solar panels. However, many PV installations are still connected to the electricity grid. This means that when there is **surplus** power – when electricity is being produced by the solar panels faster than it is needed in the home – it is fed <u>into</u> the grid. If consumption **exceeds** production – if electricity is being used in the home faster than the solar panels can produce it – then power is taken <u>from</u> the grid. Homes with low consumption may therefore become **net** producers of power, producing more electricity than they consume.

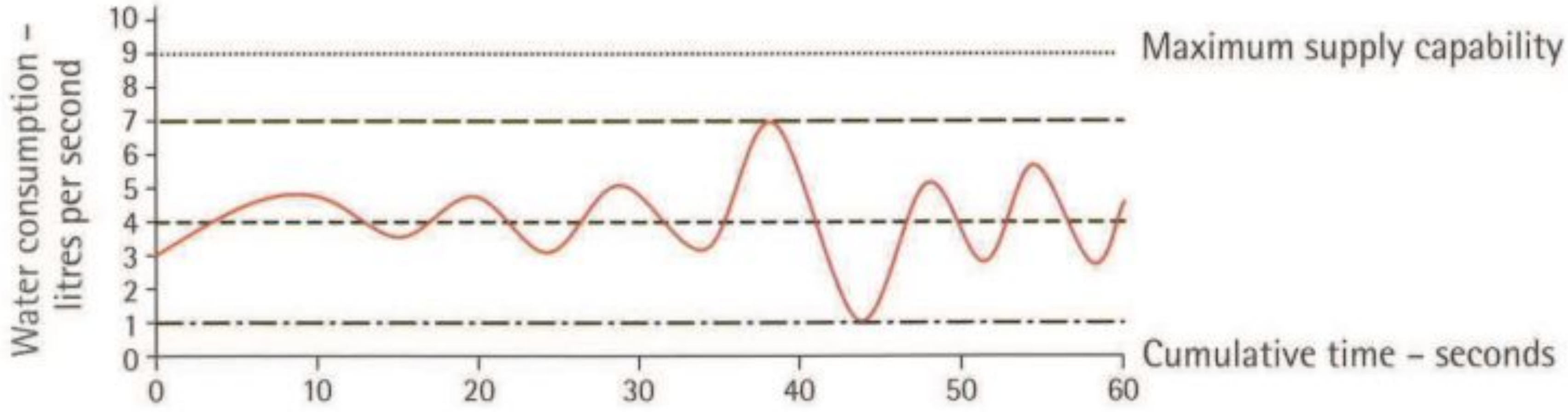
An engineer is talking to a colleague about the design of a fuel tank for a water pump. Complete the explanation using the words in the box. Look at A opposite to help you.

average	constant	consumption	duration
capacity	consume	cumulative	rate

Fuel (1) .... for this engine is about 1.5 litres per hour. Of course, sometimes it'll (2) .... a bit more, sometimes a bit less, depending on the workload. But 1.5 is an (3) .... figure. And let's say the (4) .... of a work shift is 8 hours. The pump will have to be stopped occasionally, to clean the intake filter, so it won't be 8 hours of (5) .... running. But we'll say 8 hours, to be on the safe side. So 8 hours of running at a (6) .... of 1.5 litres per hour gives 12 litres of (7) .... consumption over a shift. So if we want the pump to have sufficient fuel autonomy for an 8-hour shift, the (8) .... of the fuel tank needs to be 12 litres, minimum.

The graph below shows water consumption in a washing process at a manufacturing plant. Write figures to complete the comments. Look at A opposite to help you.

1 Water consumption fluctuated between .... and .... litres per second.
2 Averaged out over the period shown, consumption was roughly .... litres per second.
3 Consumption peaked at a rate of .... litres per second.
4 If the process ran to capacity, it could use water at a rate of .... litres per second.
5 When consumption peaked, the process had spare capacity of .... litres per second.



Choose the correct words from the brackets to complete the explanations from a guided tour of a manufacturing plant. Look at A and B opposite to help you.

1 A lot of heat is generated in this part of the process. And all of that (input / output) is recycled – it provides a (demand / supply) of heat for the next stage of the process. So it's quite an (efficient / inefficient) system.
2 Sometimes, there's (insufficient / surplus) heat, and it can't all be recycled. At other times there isn't quite enough recycled heat to keep up with (peak / off-peak) demand for heat energy further along the process.
3 Some material is lost in the washing process, but the mass of water absorbed is greater than the mass of material lost. So there's a net (loss / gain) in total mass.