Electricity

Basic electricity
The measurement of electrical 'pressure' (think of water pressure) is in Volts, usually abbreviated as 'V'. e.g. 30V is thirty volts.

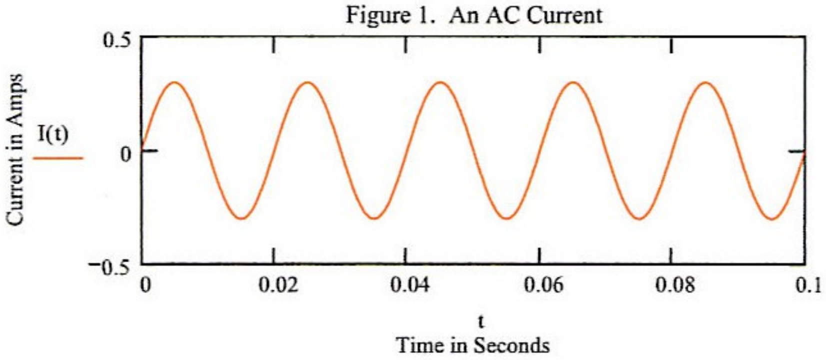
The measurement of electrical current (think of water flow) is in Amps or sometimes milliamps (1/1000Amp), usually abbreviated to 'A' or 'mA'. e.g. 100mA is one hundred milliamps (=100/1000 Amps) = 0.1A, which is nought point one of an Amp.

The measurement of the resistance to current (flow) for a given voltage (pressure) is in ohms. Think of a narrow bore pipe resisting water flow at a given pressure compared to a wide bore pipe with the same pressure behind it. That is the narrow bore pipe has a higher resistance. Ohms are abbreviated to the Greek letter Omega and written Ω e.g. 100Ω is one hundred ohms.

There are two main types of voltage which produce correspondingly two types of current. A DC or Direct Current is one which is steady, remaining at one value all the time. An AC or Alternating Current on the other hand fluctuates regularly from positive to negative and back again, in our case 50 times a second or 50Hz pronounced fifty hertz. The wave shape of the alternating current is called a sine wave and has the shape drawn in figure 1.

$f := 50 \cdot Hz \qquad I_{pk} := 300 \cdot 10^{-3} \cdot amp \qquad t := 0, 0.1 \cdot 10^{-3} .. 100 \cdot 10^{-3} \qquad I(t) := I_{pk} \cdot \sin(2 \cdot \pi \cdot f \cdot t)$

Figure 1. An AC Current



Common usage is to refer to a DC voltage or an AC voltage. The AC voltage will have the same shape as the current just illustrated but will of course have the units of Volts.

The AC voltage measured corresponds to the heating power of the voltage. For example, your kettle would boil in the same time whether you connected it to the mains (240V AC) or to 20 series-connected 12V car batteries (20 X 12 = 240V DC). The peak value of the 240V AC mains is as high as plus or minus 340V; however it just doesn't stay there for long.

The flow of current is limited by the resistance of the circuit (i.e. cable). The higher the resistance the lower the flow of current for a particular voltage impressed. A simple law called Ohm’s Law relates the entities.

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V = I x R (V equals I times R)
Where: V is volts, I is current in amps and R is resistance in Ohms

Using Algebra, also I = V / R and R = V / I (I equals V divided by R etc.)

e.g. Putting 30V across 10Ω results in a current of 30 / 10 = 3A.

Power and Energy

Energy is what does work. Driving a car up a hill uses energy, soming from the burning of fuel in the engine, producing mechanical motion and driving the wheels.

Energy is measured in a unit called Joules, abbreviated to J

Power is the rate at which energy is used or generated. It is in the unit called Watts, abbreviated W.

One Watt is one Joule used or generated every second

In electricity, Watts are calculated from Volt x Amps

so W = V x I

To get some idea of the scale of things

A kettle uses about 3 kilowatts, 3000 Watts, abbreviated 3KW

If your mains is 240V (AC) then

Amps taken by the kettle is I = W/V

I = 3000/240 = 12.5 Amps. Very nearly the 13A plug fuse on the end of its power lead.

Now for a low energy light bulb, (the fluorescent types that cost so much)

11 Watts, 240V.

I = W/V 11/240 = 0.045Amp, or 45mA (milliamps)

Hint:
move the decimal place 3 to the right to go from Amps to milliamps
move it 3 places to the left to go from millamps to Amps.

Now suppose we have a 12V (DC) bulb of 11W

I = W/V 11/12 = 0.92A, nearly a whole Amp

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Power Over Time

A battery, of whatever type, stores energy. When all that energy has been used up it is discharged. Some sorts can be recharged, by putting energy back into them

For convenience we measure battery capacity in Watt-hours. (The dash in the middle is not an arithmetic minus sign) It is sometimes abbreviated as Wh ,or mWh

Another useful measure needs us to know the battery voltage, then we can quote the battery capacity in Amp-hours. A-h, Ah or milliap-hours, mA-h or mAh

Take a car battery. A middle sized one will have a capacity of 50 Amp-hours, abbreviated 50A-h or 50Ah.

This means as follows
draw 50A and it will be discharged in 1 hour
draw 25A and it will be discharged in 2 hours
draw 1A and it will be discharged in 50 hours

To get to Watt-hours multiply the Amp-hours by the battery voltage, in this example:
50 A-h x 12 = 600W-h Watt hours.

To get from Watt-hours to Amp-hours, divide by the battery voltage.

This means as follows
take 600W from it and it will be discharged in 1 hour (600W-h / 600W = 1 hour)
take 300W from it and it will be discharged in 2 hours (600W-h /300W = 2 hours)
take 10W from it and it will be discharged in 60 hours (600W-h / 10W = 60 hours)

For little batteries, like AA cells, things are measured in milliwatt-hours mW-h or milliamp-hours mA-h

Type	Zinc–carbon	Alkaline	Li-FeS_2	NiCd	NiMH	NiZn
IEC name	R6	LR6	FR6	KR6	HR6	ZR6
ANSI/NEDA name	15D	15A	15LF	1.2K2	1.2H2	?
Capacity under 50 mA constant drain	400–1700 mAh	1800–2600 mAh	2700–3400 mAh	600–1000 mAh	600–2850 mAh	1500–1800 mAh
Nominal voltage	1.5 V	1.5 V	1.5 V	1.2 V	1.2 V	1.65 V
Max. energy at nominal voltage and 50 mA drain	2.55 Wh	3.90 Wh	5.10 Wh	1.20 Wh	3.42 Wh	2.97 Wh
Rechargeable	No	No	No[3]	Yes	Yes	Yes

in this picture milliamp-hours are abbreviated as mAh

remember, there are 1000 milliwatts in a Watt and 1000 millamps in an Amp.

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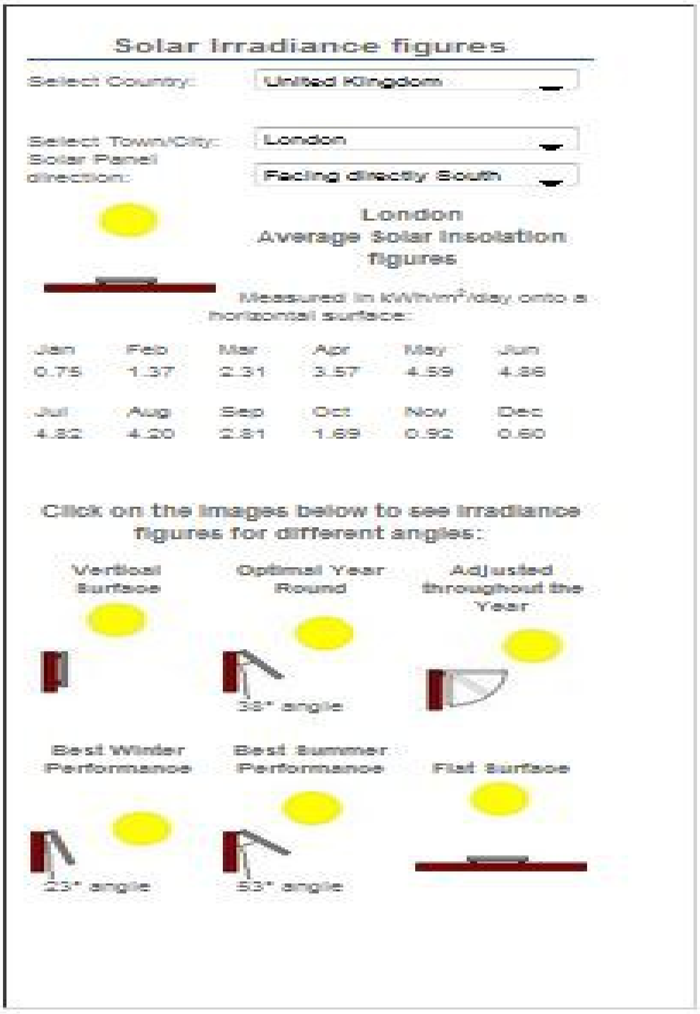
Solar Panels:

These take energy from the sun and convert it to electricity. The bigger the area of solar panels, the more electricity they generate.

Here is an example taken from this useful link

http://solarelectricityhandbook.com/solar-irradiance.html



It is for London, with the solar panel flat on the ground.

The units are quoted in $kWh/m^2/day$.

This means kilowatt-hours per square meter (of panel) per day

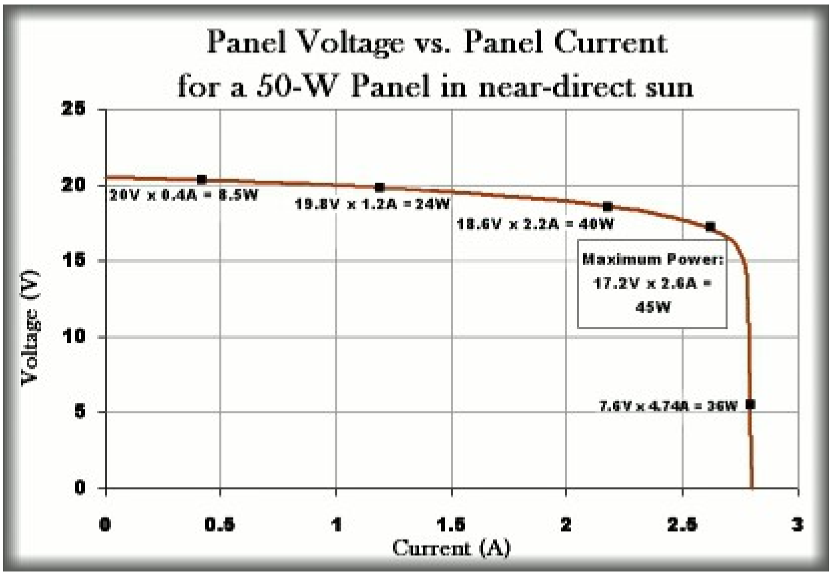
So in June, at London, on a sunny, cloudless day, in one day, a 1 square meter panel will have 4.86 Kilowatt-hours of solar energy falling on it.

However the panel is only 18% efficient, so this figure must be multiplied by 18 percent = 18/100

So the electricity it can produce in this example is 4.86 x 18 / 100 = 0.87 kilowatt-hours, or 870 Watt-hours in the whole day.

To get to Amp-hours from Watt-hours, divide the watt hours by the solar cell output voltage.

This electricity comes at a particular voltage, which depends on the type of solar panel. Normally there are several solar panels connected in, so called, 'series', where their individual voltages add up. This is illustrated in the following picture



You can see that with no current taken out of it the panel will produce just over 20V DC. This will fall to about 17V when 2.5A is taken from it.

Out of interest, at 18% efficiency and with the peak solar radiation at 1 kilowatt for each square meter of panel, the size of this panel will be ….

1000 x 18 /100 = 180Watts per square meter of electricity produced

This is a 50 Watt panel so its area is 50/180 = 0.28 of a square meter. Take the square root to find the dimensions of a square panel = 0.53 of a meter or 53 centimetres by 53 centimetres.

Don't forget this is full sun, blasting in the middle of the day, with no shade or clouds.

Converting Electricity to a useful voltage.

In the above example, 17-20V DC is not a particularly useful voltage. Plug it into your iPhone and it will go phut! Put it into a 12V car bulb and it will burn out.

There are a great number of electronic circuits which can take this sort of voltage and produce either 5V for your USB charger, or 115V AC or 240V AC to run your laptop.

The clever stuff is to make this conversion efficiently, it is never 100%.

Depending on the circuit, the conversion efficiency will be 65-80%. This means you have to multiply the solar cell output by 75/100 to 80/100.