How the solar motor works.

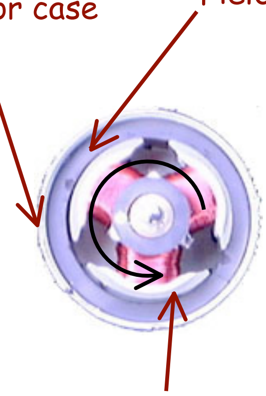
An electric motor transfers electrical energy into mechanical energy.

The solar motor is a small direct current (dc) electric motor. Electricity flows through the motor in one direction only.

The motor is sealed for life but we've taken one apart to look at how it works.

Identifying the working parts.

When the steel back is removed from the motor case.

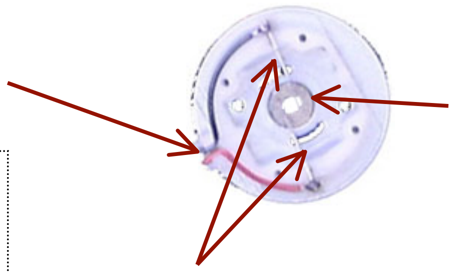


The armature with 3 curved poles and red windings spins inside the motor.

The armature & field magnet are very close but do not touch

Fixed inside the case is a circular field magnet.

Inside the steel back



A bronze bearing provides low friction mount for the spinning armature.

Positive and negative connection wires leave the motor case.

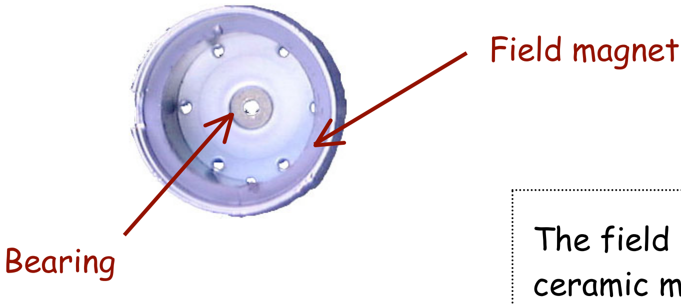
They conduct electric current to brush contacts.

Two stationary brush contacts make low friction electrical contact with spinning armature.

Tel/Fax 0114 249 9459 www.pluggingintothesun.org.uk

With the armature removed from the steel case we get the following view:

Inside the steel case



A bronze bearing provides a second mount for the spinning armature.

The field magnet is made from a ceramic material.

This permanent magnet creates a stationary magnetic field inside the motor.

The field magnet attracts and opposes magnetic poles on the armature.

Tel/Fax 0114 249 9459 www.pluggingintothesun.org.uk

Armature.

The armature is everything inside the motor that spins.

It comprises a spindle, commutator, stack and windings.

The stack and commutator are mounted on the spindle.

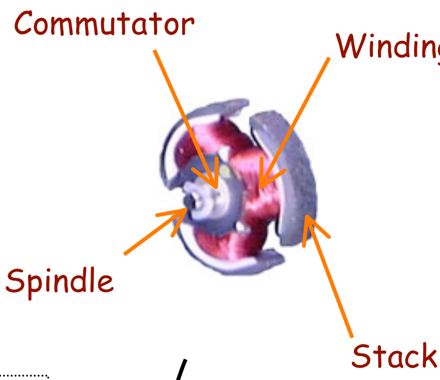
The windings are mounted on the stack.

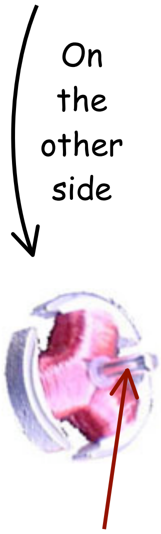
Commutator.

The commutator controls flow of electric current through the windings as the armature spins.

Reversing the current in a winding flips the polarity of that pole.

The magnetic fields produced by the poles interact with the fixed field produced by the field magnet.





Stack.

The stack (made of 'soft iron') is shaped to have 3 separate poles.

Each pole is wrapped in a wire winding to form an electromagnet.

A pole becomes magnetised when electric current flows through the winding.

The polarity of the pole depends on the direction of the current.

'Soft iron' does not stay magnetised after the electromagnet is switched off.

Windings.

Each winding is made from 8 metres of thin copper wire with many loops.

The wire is coated with insulating red enamel so current flows along the full length of the wire around the winding, not jumping across the loops.

The two ends of each winding are soldered to adjacent segments on the commutator.

White plastic tape further insulates the wire winding from the stack.

Spindle.

This part of the spindle extends through the front of the case forming the output shaft of the motor.

Tel/Fax 0114 249 9459 www.pluggingintothesun.org.uk

When the motor is connected to an illuminated PV cell:

When the black and red motor wires are connected to a power source a current flows through the motor.

One brush contact is positive and the other is negative.

The winding goes round one of the poles of the armature forming an electromagnet.

The pole becomes magnetised so it experiences a force from the field magnet.

The force creates a torque (turning force) on the armature so it turns if the force is large enough.

When the armature turns each electromagnet moves away from one pole of the field magnet and towards the other.

Changing the direction of the current through a winding flips the electromagnet's field direction.

The magnetic field that a winding experiences from the permanent magnet changes polarity every half revolution.

Armature is moving through magnetic field produced by field magnet.

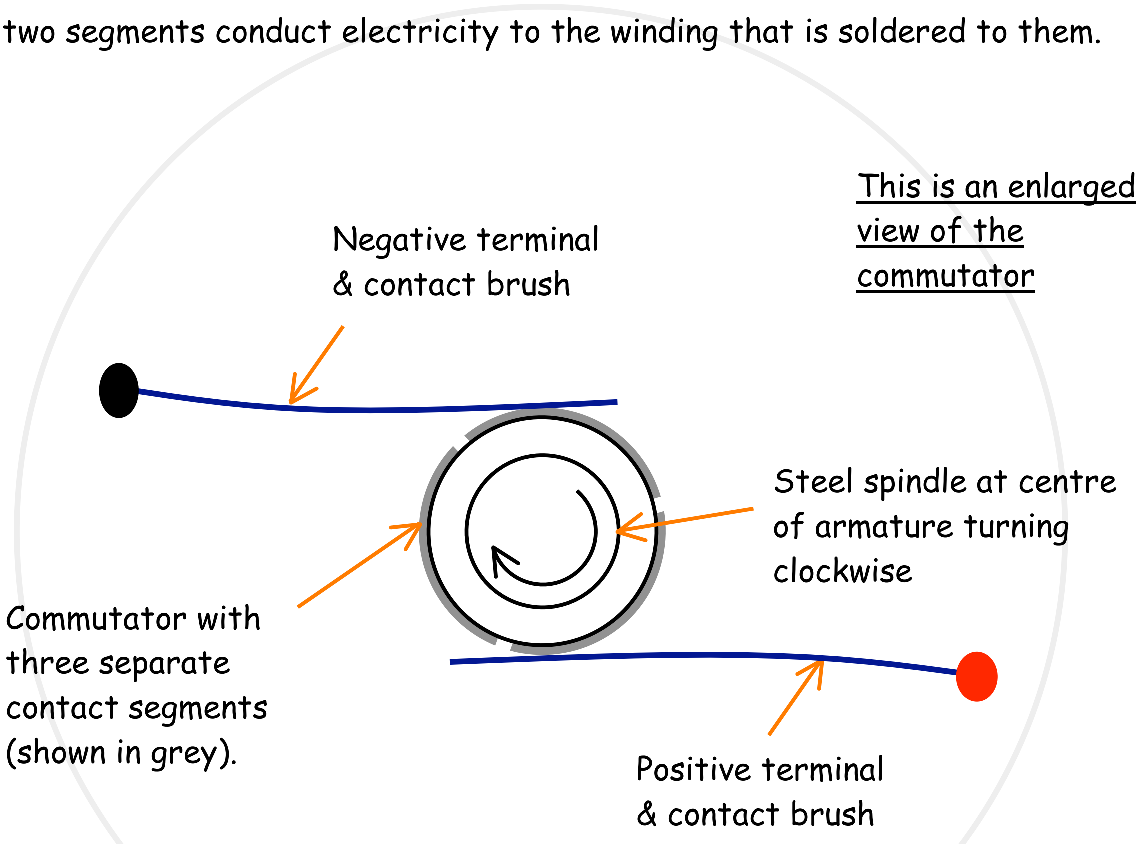
Tel/Fax 0114 249 9459 www.pluggingintothesun.org.uk

How are the electromagnets turned on and off in the correct sequence and with the correct field direction?

To maintain rotation, the current through each winding is reversed during each half revolution by means of the brushes making contact with different segments on the commutator rotating with the spindle.

The brushes make contact with two of the three segments on the commutator.

The two segments conduct electricity to the winding that is soldered to them.



In the diagram the top segment is in contact with the negative terminal. The segment on the right has just made contact with the positive terminal. The segment on the left is contact with neither terminal.

In this position it is the winding that is soldered to the segment at the top of the diagram and the segment at the right of the diagram that will be energised. The pole is magnetised - its polarity depending on the direction of the current flow through the winding.

However when the commutator turns a little further (1/6 of a complete revolution) the segment at the top of the diagram will break contact with the negative brush and the segment currently at the left of the diagram will make contact with the negative brush. A different winding is now energised.

The following table shows the switches made during 1 complete revolution of the commutator:

Rotation of armature	electromagnet 1	electromagnet 2	electromagnet 3
1/6 revolution	On 'north seeking'	Off	Off
2/6 revolution	Off	On 'north seeking'	Off
1/2 (3/6) a revolution	Off	Off	On 'north seeking'
4/6 revolution	On 'south seeking'	Off	Off
5/6 revolution	Off	On 'south seeking'	Off
1 (6/6) complete revolution	Off	off	On 'south seeking'

See the next section for an explanation of 'north seeking' & 'south seeking'.

Science behind the technology.

Magnetic Polarity.

Magnets show attractive and repulsive forces.

Like poles (North & North or South & South) repel each other.

Unlike poles (North & South) attract each other.

Another term for a North pole is 'south-seeking'.

Another term for a South pole is 'north-seeking' (like the point of a compass needle).

Electromagnetism.

The motion of electric charge creates a magnetic field.

When an electric current flows through a wire a magnetic field is created around the wire.

The solar motor has a permanent field magnet fixed inside.

A permanent magnet does not require an electricity supply and the field direction does not change.

The spinning motion of electrons in the atoms of the magnet (in this case a ceramic material) creates a magnetic field.

Tel/Fax 0114 249 9459 www.pluggingintothesun.org.uk

Each pole of the armature is an electromagnet.

An electromagnet needs an electric current to operate so it is not permanent.

The current of electrons flowing through the winding creates a magnetic field.

The magnetic field direction depends on the direction the current flows through the electromagnet.

Reversing the current flips the magnetic field direction and the polarity of the poles.

The permanent magnet fixed to the motor case and the electromagnets fixed to the spindle experience magnetic forces from each other. Usually it is the motor case that is mounted so as to be stationary. The action of the magnetic forces created inside the motor make the spindle spin.

An electric motor harnesses this phenomenon to force a shaft to turn.

Connecting the motor to another mechanism transfers torque (turning force).

Materials:

The stack contains iron atoms. Each iron atom is a tiny magnet because of the nature of its electrons.

When a winding is energised the magnetic field it creates makes the iron atoms in the stack line up with the field and each other. This has the effect of intensifying the magnetic field.

The steel case also contains some iron atoms. These further increase magnetic field intensity produced by the permanent field magnet.

Copper has a high degree of electrical conductivity. The windings of the armature are made with thin copper wire.

Low friction spindle bearings made from bronze minimise energy losses (wasted energy).

Brush contacts also minimise friction and energy losses inside the motor.

Using a solar motor.

Technical specifications:

- precision manufactured low inertia type
- outside diameter 24mm, 12mm length
- output shaft (spindle) 2mm diameter, 6mm outside length
- weight 22grams
- working voltage 1.5-4.5V
- starting current 10mA
- no load speed @2V 2200 revolutions per minute; drawing current of 0.018A
- at maximum efficiency: 1600 r/min, current 0.055A, torque 2.8 g.cm (0.27 mN.m), output 0.046 W
- stall: torque 12 g.cm (1.18 mN.m), current 0.17A

Keep the motor dry. It contains materials that will corrode if exposed to fresh or salt water.

Do not pull the connection wires. The black and red connection wires are not strong and can be difficult to repair.

Maintenance free. The motor is sealed for life and does not require any maintenance during normal use.

Connecting to PV's. Do not exceed the maximum voltage and current ratings given in the technical specifications. Remember that the voltage and current produced by a PV cell or connected cells can increase rapidly when lighting conditions are variable.

You will find further information about how electric motors work on the following websites:

www.howstuffworks.com

www.csc.uvic.ca/~tyounger/hafh/rc/motortech.html

http://fly.hiwaay.net/~palmer/motor.html