Electric Motors

Copper is an excellent electrical conductor. This is why it is used in so many electrical applications, including electric motors. We use electric motors in the home, the garden and at work.

Where are Electric Motors Used?

Lifts and escalators

Powerful electric motors drive many millions of these all over the world.

Cars

Cars have several electric motors:

1. The starter motor turns the petrol engine to get it going.
2. Other motors work the windscreen wipers, windows and mirrors

Trains

An electric train has a powerful motor to drive it.
High speed trains like the Eurostar in Figure 2 have motors for each set of wheels.

Copper windings and rotors in electric motors are driving the global revolution in transport as we move away from internal combustion to hybrid and pure electrical power. Copper in coils for power generation and motors is enabling the electrification of the world.

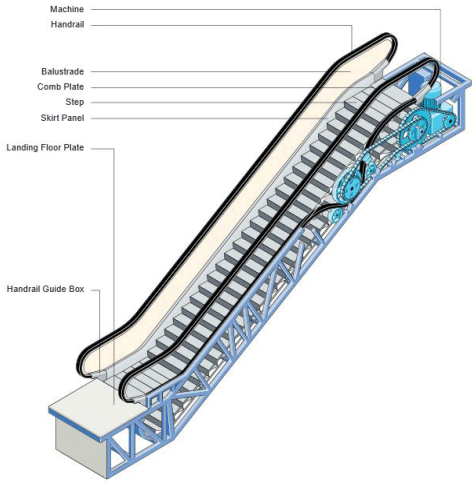

Figure 1: Click on the image for a larger view and find the motor at the top of the escalator. (Courtesy of Otis.)

Figure 2: Copper wound induction motors drive this Velaro Eurostar train from London to Paris in two hours. (Courtesy of Siemens.)

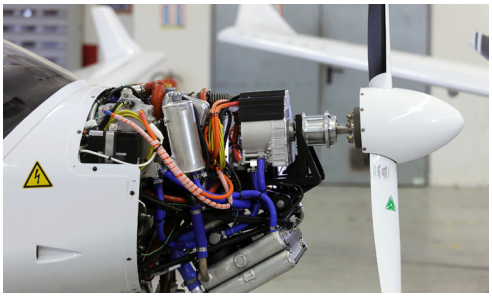

Figure 3: Electric hybrid aircraft power. The electric motor provides high power for take off and short flights without fuel. A petrol engine drives a generator for backup power and longer range. Copper cables supply the high electric current to the motor. (Courtesy of Siemens.) (Wikimedia Commons.)

Figure 4: Engineers are already researching the use of electric hybrid drives for 50 seater planes. (Courtesy of Siemens.)

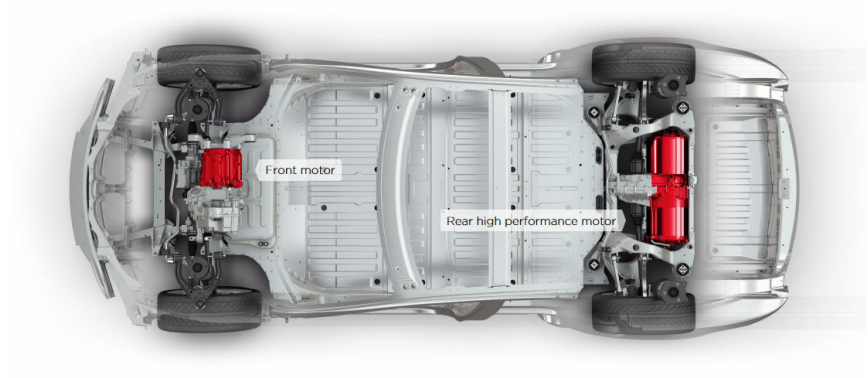

Figure 5: Electric motors are compact, light and very powerful. This twin motor layout is from a Tesla car. (Courtesy of Tesla.)

What's Inside an Electric Motor?

Rotor coil

The coil is made of copper wire, because copper is such an excellent conductor. It is wound onto an armature. The coil becomes an electromagnet when a current flows through it.

Armature

The armature supports the coil and can help make the electromagnet stronger. This makes the motor more efficient.

Permanent magnets

There are two permanent magnets. They produce a steady magnetic field so that the coil will turn when a current flows in it.

Some motors have electromagnets instead of permanent magnets (Figure 9). These are made from more coils of copper wire.

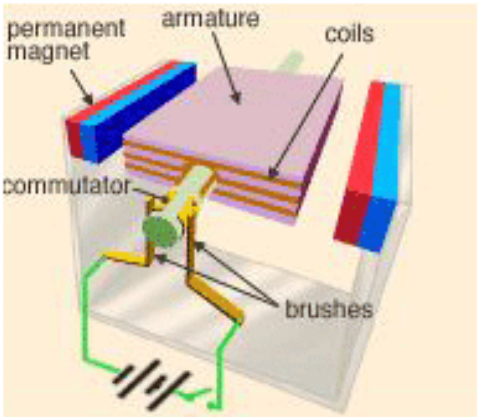

Figure 6: Parts of a model DC motor. Low voltage battery powered DC motors drive motorised toys. They are easy to take apart. You may find that they use multiple coils and have a multi-segment commutator to match.

Commutator
Each end of the coil is connected to one of the two halves of the commutator. The commutator swaps the contacts over every half turn. The rotor in Figure 8 has two coils and so needs four commutator segments.

Brushes
The brushes press on the commutator. They keep contact with the commutator even though it is spinning round. The current flows in and out of the motor through the brushes. In real motors the brushes are made from carbon.

Steel former
The former made of magnetic material links the two permanent magnets and, in effect, makes them into a single horseshoe shaped magnet.

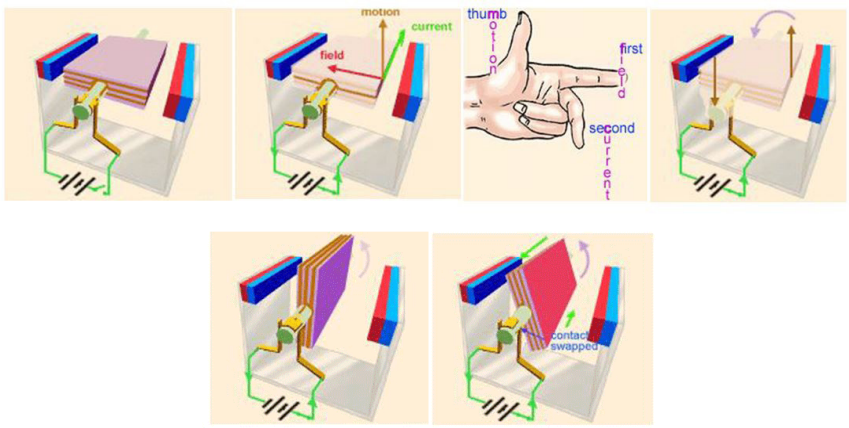

Figure 7 - A simple two pole (one N and one S) DC motor.

Why Does it Turn?

The page on electromagnets shows how a coil of wire becomes a magnet when electric current flows through it. The motor coil wound onto the armature becomes an electromagnet, but the electromagnet is situated inside a second permanent magnetic field. These fields interact just like two bar magnets. The result is attraction or repulsion, depending on the current direction. The current flows in one direction on the right of the coil and in the opposite direction on the left.

The force on the wire is at right angles to the magnetic field and also at right angles to the current. This is called the motor effect. Fleming's rule uses your fingers and thumbs at right angles to each other to predict the force on a wire in a magnetic field. For motors you use the left hand.

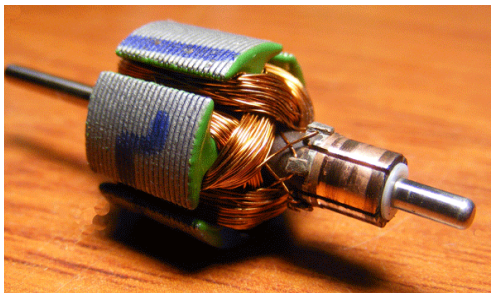

Figure 8: A DC motor rotor with coils and commutator. More coils and segments give a more continuous turning force. (Wikimedia.)

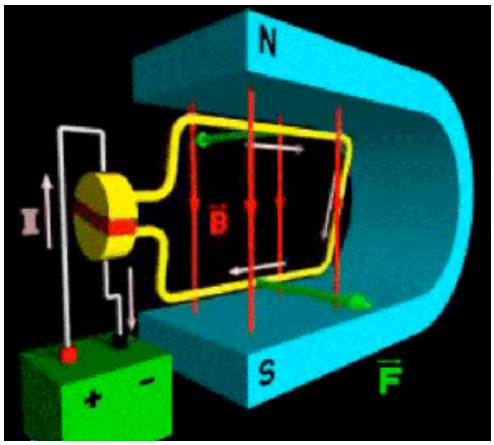

Figure 9: There are animations showing the motor effect online such as this. Search for DC motor effect animation or similar terms to find them. Watch the YouTube video and try Fleming's left hand rule on this picture. Does it work? (Courtesy of PelletierPhysics.)

Refer to Figure 7. When the current is switched on, it flows in the green arrow direction and causes an upward force. Try to match the diagram with your left hand. As it flows back down the other side in the opposite direction it causes a downward force. Move your hand to match that direction. The forces combine to spin the coil.

This can only work for half a turn. The split ring connector, called the commutator, swaps the connections over so that the next half turn can begin. This happens for each half turn so the motor spins. Electric current is fed to the coil through the brushes.

This is how a DC electric motor works. AC motors are more complicated, but Fleming's rule is still what makes them turn.

Energy Transfers Sankey Diagram

We supply electrical energy to an electric motor. An efficient motor transfers most of this energy as kinetic energy (useful work). Only a small fraction is wasted as it heats up the surroundings. We can show this in a Sankey diagram (Figure 12). The size of the arrows represents the amount of each type of energy converted from electrical energy.

Energy is lost as the electric current flows through the motor's coils. The wire coils have electrical resistance; the greater the resistance, the harder it is for the current to flow and the more energy is wasted.

Copper is a good metal to use for a motor's coils because:

- it has less resistance than almost any other metal
- it is easily formed into coils
- it is not too expensive
- it can survive to a high temperature
- it can be recycled when the motor is replaced

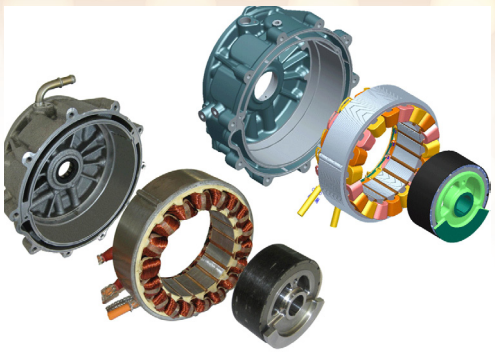

Figure 10: An exploded view of a typical hybrid drive motor (computer drawing and the real thing). The stator coils are tightly wound copper wire to create strong magnetic fields. (Courtesy of AVL.)

Figure 11: An electric motor and batteries replacing a petrol engine in a Porsche car. (Courtesy of Siemens.)

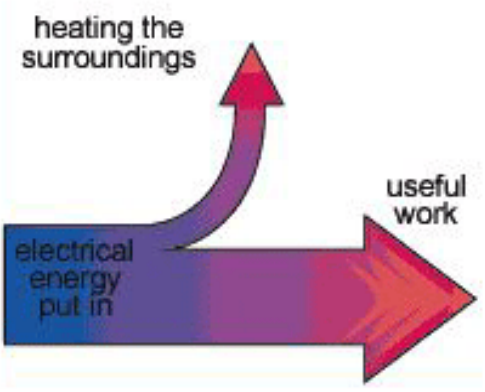

Figure 12: Energy transfers Sankey diagram.

Questions

1. Compare the motors in Figure 7 and Figure 10. The simple model motor has two poles. How many poles does the hybrid motor have?

Figure 7

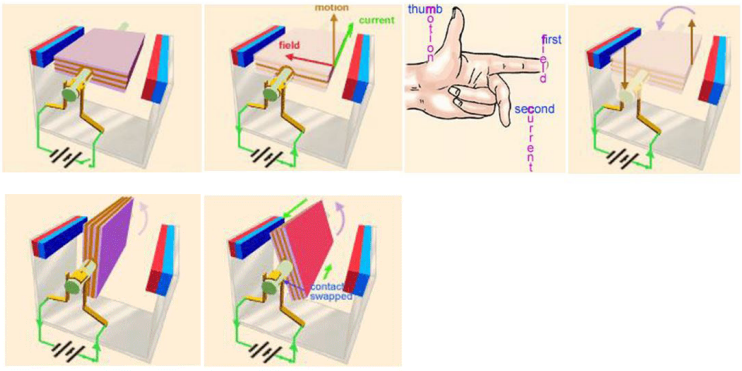

Figure 10

2. What are the advantages of electric power for the aircraft in Figure 3?

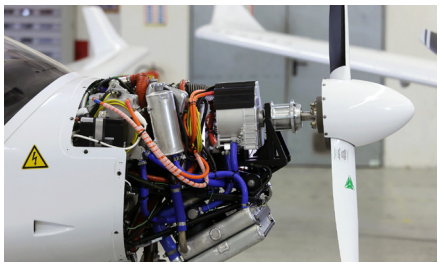

Figure 3

3. For an electric car to have zero emissions of CO_2, the battery needs to be charged from what kind of energy?

Click here for answers

Copper Development Association is a non-profit organisation that provides information on copper's properties and applications, its essentiality for health, quality of life and its role in technology. It supports education through a collection of resources spanning biology, chemistry and physics. These materials have been developed in conjunction with the Association for Science Education, and reviewed by teachers.

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