

An impressive sine wave

Geoff Auty

Students often have difficulty in understanding textbook line-diagrams illustrating the action of a dynamo, although the colour illustrations in some modern books are an improvement. Practical methods, such as those described here, can help to overcome this problem (with apologies for reliance on line-diagrams).

To aid the understanding of generating alternating current, I take the usual route of connecting a flexible wire to a sensitive galvanometer (e.g. Edspot). The wire is moved within the field of an Eclipse Major magnet to illustrate the application of Fleming's Right Hand Rule. I then pose the question of how to obtain a continuous current. It is reasoned that rotation of the wire should produce the same kind of effects as oscillation.

I made a small model with one piece of stiff copper wire (16 swg = 0.163 mm diameter) to rotate within the magnetic field created by a yoke and two magnadur magnets from the *Westminster Electromagnetism Kit*. Two pieces cut from 15 mm copper pipe act as slip-rings, with pieces of dowel to provide wooden packing, and pieces of scrap copper plate to act as contact brushes (Figure 1).

It is rather difficult to obtain convincing results from this simple generator. The induced emf is very

small, and the contact at the rings and brushes is so unreliable that the galvanometer indicates rather erratic bursts of current. Also, the magnetic field is not uniform throughout the whole region where the wire moves. I ask students to accept this as a model on the way to better things, and consider further improvement.

With a single piece of wire at one side of the central axle, the design is not balanced. It does not take long to realise that wires at opposite sides of the axle would provide balance and that if both slip-rings are at the same end, the output emf will be double that from the original model (Figure 2).

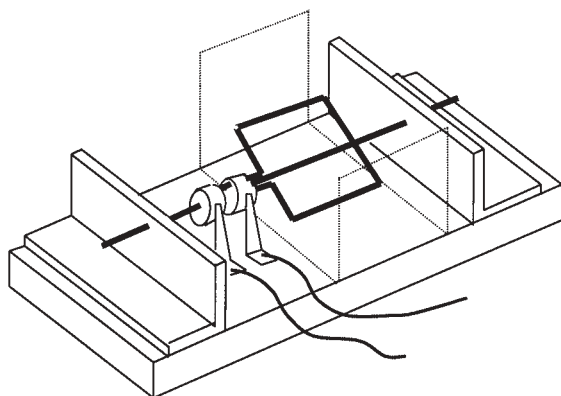


Figure 2 Model dynamo using single rotating wires on opposite sides of the axis.

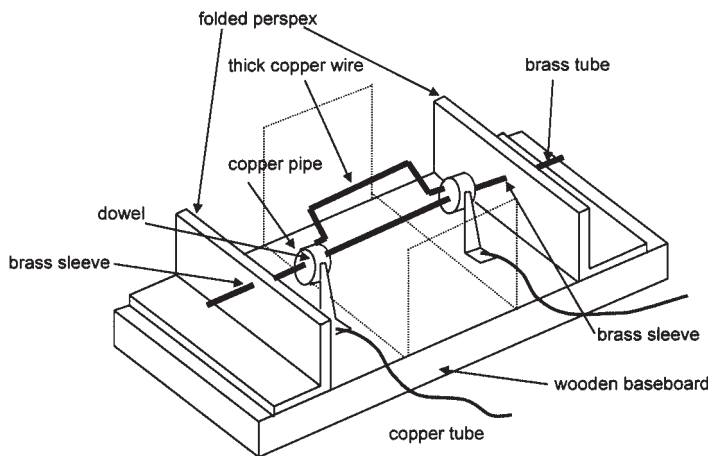


Figure 1 Model dynamo using a single rotating wire. Position for magnadur yoke is shown by the dotted lines.

This provides the basis of the traditional textbook drawing. However, I made a third model with a rectangular coil of three turns (not illustrated here because it is difficult to draw, yet is only an extension of Figure 2). This shows how a coil with many turns could be made, yet with only the ends of the coil connected to the slip-rings. The use of very thick wire means that the coil is self-supporting. So there is no need for any kind of frame or former, and the shape can be seen from any position. In particular, there is the need to draw attention to how one end of the wire passes through a slip-ring without contact, but is then connected to the other ring.

At this stage, I must emphasise that I have described solid three-dimensional models which students can handle and study, to show an item illustrated in textbooks, and which they may be expected to draw with reasonable accuracy. These models aid good artistry but were not a huge practical success, mainly due to the erratic contact as already described. Some student usually suggests spinning the coil faster. If this is the case, I return to the single flexible wire, and show that if the wire moves very quickly, the galvanometer does not keep up. The galvanometer is extremely sensitive for steady currents, but does not respond well to rapid changes.

Following these suggestions, we consider a way to observe the result of more rapid movement and avoid the problem of poor contact at the slip-rings. I suggest the possibility of inverting the logic by rotating a magnet within a coil. Not all students will immediately agree with this choice, but I propose we should try it.

To obtain a working model is very simple. The Helmholtz coils provided with Teltron equipment are fixed to the stand, and connected to an oscilloscope. I found a sensitivity of 0.5 V cm^{-1} to be suitable, with timebase setting at 10 ms cm^{-1} , but it is worth experimenting for the best observation. Remember that the coils of the Teltron equipment normally stand 'back-to-back' so that terminals are facing outwards. This provides the necessary space when used with cathode ray tubes. Hence it is worth double-checking the connections so that the magnetic fields of the coils would be additive if supplied with current. A compass needle will help if required.

Two magnadur magnets are placed on opposite sides of the steel rod unscrewed from a clampstand. They cling very well if opposite poles are facing, but slide around to meet each other due to their strong attraction. However, it is quite easy to hold the

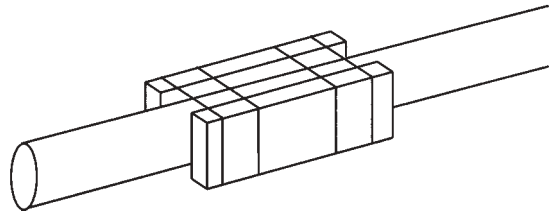


Figure 3 Magnadur magnets fixed to the rod obtained from a clampstand.

magnets on opposite sides with one hand, and wrap them with two strips of Sellotape. We then have magnets firmly fixed to the rod with opposite poles facing away, providing in effect the field of one central magnet (Figure 3).

One end of the rod is placed through the centre of the Teltron stand (Figure 4). The other end is rested in a clamp with the jaws not quite closed, and at a level which allows the rod to be horizontal. The magnadur magnets are just slightly below the centre between the coils. A piece of string is tied to the rod and wrapped about 12 times around it. Then a firm pull on the string produces consistent rotation and an impressive wave is displayed on the screen of the oscilloscope. This provides convincing evidence of an alternating voltage.

One could consider having the system driven by a motor, but I have found that students generally give approval to this simple arrangement, especially if we have time to repeat the observation, or better, let them try for themselves to produce ac using a piece of string (a 'who got the best looking waves' competition).

The observation leads to discussion of the bottle-shaped dynamo for use on bicycles, and the design of generators in power stations where the rotating part is an electromagnet (taking an input current through contact brushes) whilst three sets of stator coils deliver the 3-phase ac.

It may be necessary to consider why we changed from a galvanometer to an oscilloscope for detection and students usually ask. If there is time, another demonstration is to consider the limitations of the galvanometer.

Connect a signal generator to an oscilloscope at the X-input. Also connect the signal generator to the Edspot galvanometer or similar, with a large resistor in series. As the galvanometer is sensitive to currents of the order of a fraction of a microamp when on its undamped setting, this resistor must be around 1 megohm. The actual value of resistance will depend on your own equipment.

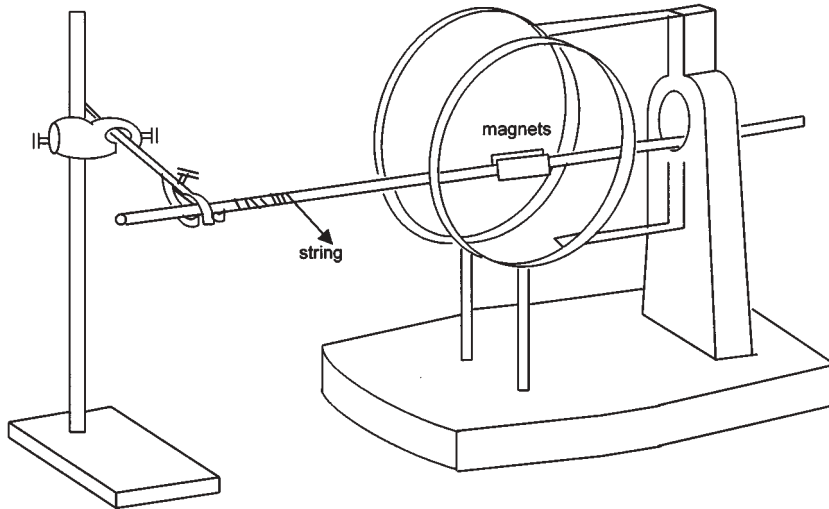


Figure 4 Arrangement to produce sine waves using a rotating magnet.

Set the signal generator to its lowest frequency (less than 1 Hz is most impressive), and then turn up the amplitude gently. The spot on the screen of the Edspot will move in synchronisation with that on the oscilloscope. Adjustment of the resistor value or the oscilloscope sensitivity will allow both movements to have about the same amplitude.

Then turn the frequency to larger values to see that the display of the oscilloscope progresses from

an oscillating spot to a horizontal line, but the spot on the screen of the galvanometer gives up the struggle and remains at the centre, apparently indicating no current. With care it is possible to find a frequency at which the spot seems stationary when viewed from a distance but shows very small vibrations when viewed closely.

Geoff Auty teaches physics and electronics at New College, Pontefract.

■ A new twist in circular motion

Geoff Auty

This is an example where logic seems to defy instinct to produce a result which was at first unexpected.

When dealing with circular motion with an A-level (year 13) physics group, our discussion went towards 'loop-the-loop' and various fairground attractions. These included one sometimes entitled the 'Wall of Death', in which motorcyclists start from the centre of a cone-shaped arena and eventually ride around vertical walls. I offered to simulate the effect and chose a plastic funnel with a vertical section near the top

rim. I used a small piece of paper towel to plug the neck and placed a ball-bearing in the cone. Then, holding the stem of the funnel, I began to move it in a circular motion, causing the ball-bearing to run around the sloping walls (Figure 1) and eventually to run around the vertical rim. Once the track is established, it takes very little effort to keep the ball-bearing moving, and students can see quite clearly what is happening as it moves around an almost stationary cone.