

615-4740 (45-075) Induction Kit

Description:

Our Science First Induction kit has been carefully made so that the molded pieces snap together easily. This kit is designed to allow students and teachers alike to construct, examine and experiment with the many aspects of electromagnetism. This includes assembling motors and transformers, measuring amperages and voltages as well as performing a large range of experiments.

Curriculum Fit: Electromagnetism, Transformers, Measuring Amperages, and Motors.

Safety Note: This kit has been designed for use with 12V power supplies only. Use with other power sources will irreparably damage the components.



INTRODUCTION

Science First has designed this kit for maximum flexibility and adaptations for a variety of configurations are possible. The AC motor supplied is typical of those used in everyday applications. Transformer theory and practice can also be clearly understood from both a theoretical and practical standpoint.

STUDENT'S NOTES ON ELECTROMAGNETIC THEORY

In theory, electrons (which are negatively charged) flow from the more negatively charged potential to the more positively charged potential. In the conventional model, a magnetic field is usually thought of as flowing from the North pole of the magnet to the South pole of the magnet.

For this kit, we will use the conventional model of electron flow.

Consider that unlike poles attract in your study. When using a simple compass to detect current flow, the north pole of your compass will actually point to the South pole.

Also keep in mind that when looking at a simple lamp circuit, if current flow is from positive to negative, then inside the battery it must be flowing from negative to positive. These visualizations will assist when using the kit.

Other concepts that will be of help are the Left-Hand Rule for motors and the Right Hand Rule for Generators. Your teacher will explain the detail of these principles.

There is also one other concept, entitled "the Right Fingers Rule" for magnets. This determines which end of a solid iron core will become North when current direction in a coil is known. For example, if current flows counter-clockwise through the coil windings then North will be up and vice versa for clockwise flow.

DEFINITIONS

AC: Refers to alternating current. This current flows back and forth as a sinusoidal waveform and does not have positive and negative polarity.

BOOST: is where one voltage adds to another in a transformer winding connection.

BUCK: is the reverse of boost. Windings are arranged so that one voltage subtracts from the other.

CAPACITOR: This is a component that can store charge. This charge can be stored and released at a predetermined time. This charge occurs when the AC wave value falls and recharges as it rises. Capacitors can be used to smooth DC current.

CHOKER: This in simple terms is an iron type core to which is fitted a single coil which has the effect of creating a reverse voltage which opposes the applied voltage thus tending to stem the current flow through the coil.

CORE: Refers to the central “core” used inside wound coils to create a more efficient magnetic field. It may be iron or ferrite that is a ceramic/iron composite.

DC: is a term referring to direct current that flows in one direction only from positive to negative. It is smooth when supplied from a battery but may have a pulsating component when supplied from a rectified AC supply.

EMF: stands for electro motive force and in simple terms is created in a generator and is forced through the conductor when the circuit is closed (switched to ON). The quantity flowing depends upon the generating force of the generator and the resistance within the circuit being used. (ie device used, wire resistance, etc).

FIELD: refers to the magnetic lines of force surrounding an iron core such as a permanent magnet or an iron core energized by windings.

FILTER: is a device connected across a DC circuit which tries to remove the peaks and troughs so that the available current is perfectly smooth. It often consists of a large capacitor. Although more complex electronic circuits can achieve similar or better results, the simplicity of the filter makes it desirable for most applications.

FLUX: refers to the density or strength of a magnetic field. It is often used to denote the power of permanent or electro magnets.

FREQUENCY: now correctly called Hertz, is the number of times per second that an alternating current wave passes through one full cycle (trace on an oscilloscope) from zero to maximum and then falling to its lowest point and rising to zero again.

INDUCTANCE: depends upon the number of turns in a coil wound around an iron or ferrite core. The inductive effect or “strength” is measured in a scaled called the Henry.

INDUCTION: means the creating of a voltage in a wire by means of exposing a coil of wire to a magnetic field, often from another coil. Usually, the two coils are not connected to each other electrically.

INDUCTOR: is simply a coil of wire around a ceramic or iron core.

LAMINATIONS: in AC applications are strips or sheets of iron which are insulated electrically from each other and are assembled so as to create an iron core but with the property of eliminating inefficient circulating currents. These can be seen in transformer cores.

LEAKAGE: refers to any current appearing outside the iron core in a transforming device and every effort is made in design to eliminate these as they cannot be utilized in working the secondary coil.

LOSS: We define Loss as the amount of energy provided by the Primary coil, but are not available to the secondary. When transforming current from a primary to a secondary coil, certain factors create current loss. Some of these are the winding resistance, leakage and energy dissipated in the magnetizing/demagnetizing process when using AC current to the primary.

MAGNETIZING CURRENT: refers to the current taken from the power supply by a primary coil to magnetize the iron core and to overcome the leakage and losses.

PHASE: is the relationship that two voltages, or two currents, or a voltage and a current bear to each other. DC voltages and currents are generally in phase with each other, whereas AC voltages may not depending upon how the secondary coils are wound. If they are connected in series the voltage will add to each other whereas in an opposite direction it will subtract. An interesting experiment is to examine coils wound the same direction or in opposite directions, then apply current and compare them on an oscilloscope.

PRIMARY: means the winding on a transformer that is connected directly to the power supply and must provide sufficient current to magnetize the iron core as well as transfer to the secondary winding and give the desired output.

REACTANCE: When we consider DC current we must think of resistance (which is measured in Ohms) which controls current flow in a circuit and generates heat (which is measured in watts). Contrasting that to AC current, we still have resistance but we also have what is known as reactance. This depends upon the inductance (measured in Henrys) and also the frequency of the current applied.

RECTIFICATION: is a process where AC current is converted to DC (direct current). It involves using a system of special diodes in conjunction with a transformer. Depending on the number of diodes used either half wave or full wave rectification can be achieved. If one diode is used, half the AC wave form is passed through the diode. Four diodes allow the entire waveform to pass. Rectification is reserved for the realm of electronic study and is not fully covered by this kit.

RELUCTANCE: this is the characteristic of a material to support a magnetic field substances such as copper, brass, aluminum or even air have high reluctance whereas iron, cobalt, nickel have lower varying degrees of reluctance. Transformer cores usually have a very low reluctance.

RESISTANCE: this refers to the ability of a material to allow electrons to freely flow through it. Metals generally have low resistance whereas materials such plastics, glass, ceramics or diamond have very high resistance. Materials with low resistance are called conductors, and materials with high resistance are called insulators. The unit of resistance is Ohms (Ω).

ROTOR: is the central component of an electric motor that moves within a commutator or field windings. It is often a coil itself and is the driving component of a motor.

STATOR: the word is derived from the word static and refers to the outer non-rotating part of a motor. The stator often provides the magnetic field needed in motors.

TAPPING: this is a connection point somewhere on a coil winding...in a coil of say, 100 turns, every 5th coil may be tapped. It is an allowance is made to connect a circuit at that point. many voltages can be derived from the one wound coil in this way.

TRANSFORMER simply this is a unit where a number of coils of wire are coupled together by an iron core. If a magnetic field is produced in one coil, the primary, this induces a current in the second coil or coils. Using this kit will allow various transformers of varying configurations to be observed. Coils set up in this fashion allow voltage to be transformed.

VOLTAGE: can be thought of as the electrical pressure created in a conductor when that conductor moves or rotates relative to a magnetic field, cutting the lines of magnetic force. Voltage is dependent on the strength of the field and the speed of the rotator. A voltage can be created by a generator or even by chemical means such as batteries, solar cells or even electro statically.

WATTS: when a current flows through a resistance, even if it is a very low resistance, some heat will be generated by the flow of electrons. This power is called watts. For direct current, volts x amps=watts. Alternating current follows more complex laws, and is not covered in this kit.

WINDING COILS

The kit provides two wound coils. The primary coil has 300 turns and the secondary has 600 turns. Please exercise care in using DC with the coils, as they can get very hot. A good policy is to use lower voltages from the power supply: 2, 4 or 6 volts. These coils are terminated in 4mm sockets to allow easy use of leads and connections. However, a lot of work can be done winding coils yourself of different numbers of turns; simple termination is allowable or you may like to permanently terminate your winding with the 4mm hardware supplied, or keep these as such for future use.

To wind a coil slide, slip one end of the wire supplied through the coil end aperture and begin winding counting the coils as required terminating through the other aperture and tying off or terminating with the terminals supplied and not forgetting to solder the ends to the tags

Carefully identify the wound coil with the number of turns you have wound, as this will be needed to calculate and measure your experimental work. Also clearly identify the direction in which you wound the coil as this will have a bearing on results and is needed in setting up much of your AC transformer work. The direction is required to predict the polarity of the induced EMF. Also if the coil is turned upside down the coil winding will be reversed, so there is a direction and a top and bottom to your coil.

Note that in AC work if the coil is turned upside down the phase voltage will be reversed. Refer to definitions to check these principles.

NOTES ON INDUCTION

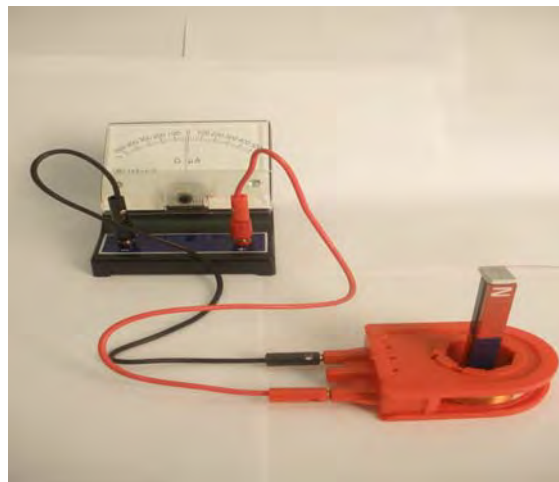
When a conductor is moved in a magnetic field, such as a coil of wire, a small voltage (electro motive force) occurs (or is "induced") while that conductor moves. If the conductor moves in the opposite direction then the EMF or voltage reverses. When the conductor is at rest then the voltage cannot be induced. Current can only be induced while the conductor cuts across the lines of magnetic force. If the strength of the magnetic field or the speed of the conductor is increased, the induced current will also increase.

Note: very sensitive instruments may be required to detect the induced current. Given the strength of the magnets in the kit, the EMF generated is often very low. To help counteract this, we suggest using as many turns of wire as possible.

For this experiment, make a coil of wire and attach the loose ends to a galvanometer. If you prefer, you can use one of the pre-wrapped coils included in the kit. Place this coil over one of the arms a horseshoe magnet and move it up and down vigorously. Record how much voltage is generated. See figure below:



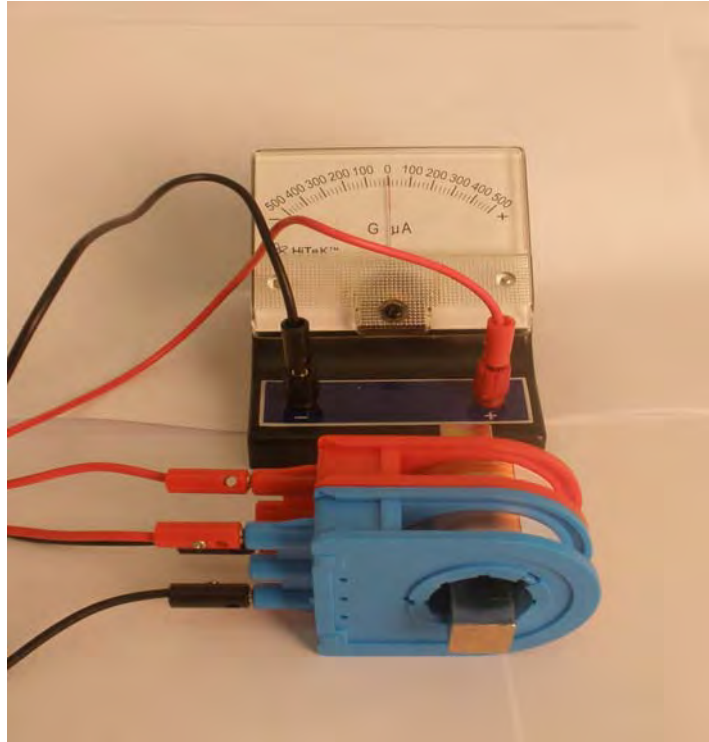
It is also possible to create a current by leaving the conductor stationary and subjecting it to a moving magnetic field. Using the same coil as the above experiment, place a bar magnet in the center. Hold the coils as still as possible and move the magnet up and down. Record the voltage. See figure below:



Changing the polarity of the magnet or the direction of the coil will change the way the galvanometer deflects. Magnets have a north and South Pole, and the coils are wound clockwise or counterclockwise. To change either value, simply turn the magnet or coil upside down.

CHANGING THE FIELD USING DC

By using two coils as provided in the kit you can prove that it is not necessary to use a permanent bar magnet to create induction. Apply 4 volts to one of the primary coils (300T) and insert an iron rod through the center the bar magnetizes. Use your knowledge to determine the North/South direction of the magnetized iron bar and prove using the compass. Now, place two coils side by side, connecting one side to the power supply and the other coil terminals to a 600-0-600uA meter. Apply current and note when applied the other coil causes the meter to deflect briefly. This occurs when the magnetic field is first created and when the power is disconnected the meter will deflect briefly in the opposite direction. This happens when the magnetic field collapses. Now repeat the experiment, but this time use an iron rod place through the two coils. Since we are no longer coupling the coils with air but with the iron rod, the deflection of the meter will increase considerably, which proves that a core makes for increased magnetic coupling. See figure below:

**CHANGING THE FIELD USING ALTERNATING CURRENT:**

Using the same items as the preceding section (DC), set up the two wound coils and place the iron rod in the center. Connect to a standard bench power supply and apply 6 volts AC to one coil, with the other coil connected as before to a center reading galvanometer 600-0-600uA. Because AC reverses its direction about 100 times a second, the induced electro motive force in the other coil will reverse 100 times per second. Because this is so rapid the meter mechanism will not be capable of moving that fast and will appear as a slight vibration and then will appear stationary. At this point, connect an AC voltmeter or better still an oscilloscope to clearly observe the AC sinusoidal wave form. Following on we have constructed a simple operational transformer to which we applied AC current and a continuous AC voltage is being generated in the other coil.

THE PURPOSE OF USING A TRANSFORMER

Consider what we have learned so far. We have established that an electromotive force is made in the secondary coil when the direct current magnetic field is altered. This EMF ceases when the field from the primary coil is constant, but if AC current is used and the field is continually rising and falling and reversing (100 times a second with a 50Hz supply to the primary coil), a continuous EMF is generated in the secondary coil. Thus a useful quantity of energy is being transferred from one coil to the other. In this case, the transformer core is the coupling mechanism between coils and if the coils have the same number of turns then the voltages in each will be the same. If they have a different number of turns then the secondary voltage will vary from the primary. This is a function of the number of turns that the primary bears to the secondary. If the turns on the secondary coil are half those on the primary coil, then the output will be half of the primary

input, and so on. Your standard bench power supply works like this: an input of 110 volts AC enters the primary coil, and the secondary has tapping (connections) at certain points to give the 2 volt steps. Note that in this case there is another component used called a rectifier which makes the secondary AC voltage into the familiar 2 to 12 volts DC we use in the laboratory. Since the primary and secondary are not connected electrically but by induction then the dangerous input voltage is isolated, allowing a safe supply on the output side. Depending upon the output voltage needed the secondary can have many hundreds of windings down to just a few where very low output voltages are required. A general rule is that if the secondary has many turns then the current (amperage) can be quite large: some power supplies convert 110V AC into 6kV DC.

Secondary coils can also be connected in multiples, either in series or parallel to give the desired outputs.

CONSTRUCTION OF THE TRANSFORMER CORE

This vital coupling device must be as efficient as possible to avoid losses in the transforming process, because when creating an AC field the lines of force (flux) cut the turns in the secondary coil and produce a voltage. Current can only flow from the secondary coil when an external circuit is connected.

This also cuts the iron core and iron, as we know, is a conductor. A small voltage is induced across the thickness of the core and because of this a strong current begins to flow inside the iron core rather like if it were a secondary coil, but with a short circuit. This takes energy from the primary coil and as well begins to heat up the iron core.

We can prove this by using the laminated transformer top. Connect an AC ammeter in series with the primary coil and apply 12 volts AC. Note the current (amps) flowing into the primary coil. Then remove the top laminated transformer part and replace with the solid iron bar. Measure the current again using the same AC meter. See figure below:

USING THE TRANSFORMER

Select the laminated U core and the laminated I core. Place the 300 turn primary coil over one leg of the U core and place either the 600 turn secondary coil, or one secondary coil you have wound, over the other leg of the laminated U core, and carefully place the other leg of the core.

In order to “clamp” the two cores together you can use strong elastic bands over the “arms” of the assembly. This ensures good continuity and prevents air gaps between the top and bottom laminated sections, minimizing magnetic leakage.

Apply 12 volts AC to the primary coil (300 turns coil) and using an AC voltmeter measure the output voltage from the 600 turn secondary coil or a coil you have wound yourself. Using the previously explained calculations work out the secondary or transformed voltage.

You can vary the combinations: place the primary on one leg and the secondary on the same leg, and measure as above. Turn the secondary over and measure. Place two secondary coils you have wound on the other leg and measure this output. Reverse one secondary and measure again. Soon you will understand the effects of adding, subtracting doubling or canceling the output voltage. Take measurements of the current (amperage) using the galvanometer or sensitive ammeter. To check for magnetic leakage take the small axle used with the Eddy current disc and hold it close to the corners of the transformer core. If leakage is present you will feel a small vibration in the axle. You may also like to place shims of paper between the tips of the U core and the I core (thus creating an air gap) check for leakage again. Use your voltmeter to check at different primary voltages and at 12 volts AC check for differences in the coil magnetizing current.

You will note the primary coil current taken to magnetize the iron core is wasteful and good transformer design avoids this by using laminations. Much of the energy is “transformed” into heat rather than useful secondary current. Try leaving the bar in place for several minutes and note the temperature increase. You can graph the increase in temperature versus time as an interesting side activity.

The purpose of using a laminated core (many specially cut pieces of iron bonded together) is to stop these circulating currents directing this lost energy to the useful output in the secondary coil. Examine any available transformer, or electric motor: if they use AC they will have laminated cores.

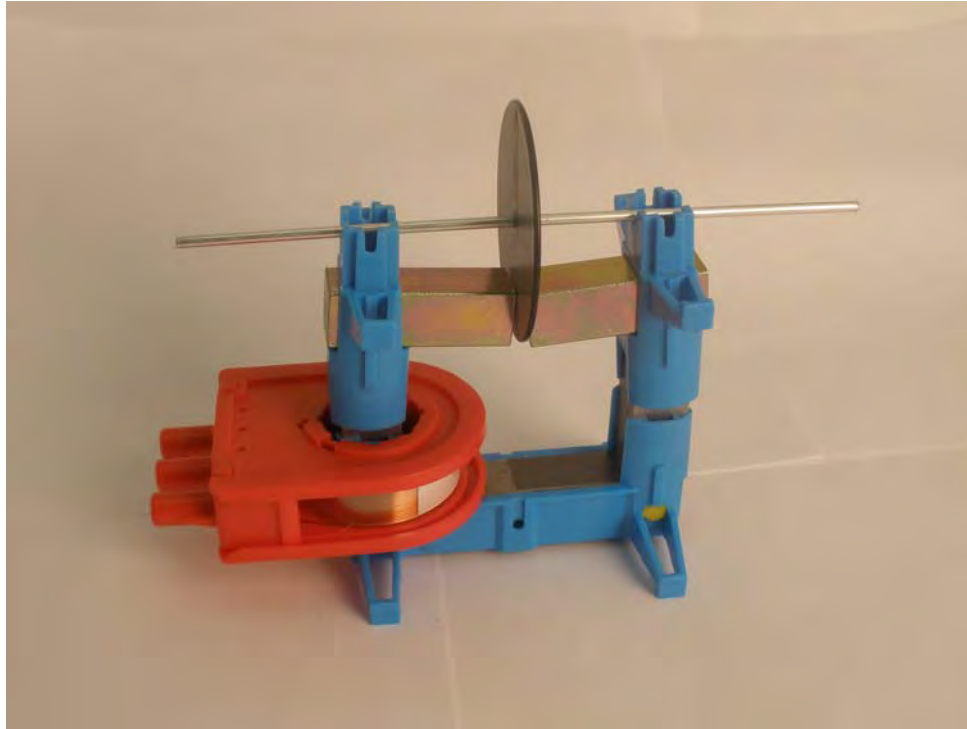
In contrast, a DC motor will not have a laminated core because the magnetic flux is constant and not cutting the iron core at 100 times per second (when using 50Hz AC). Circulating currents may also be referred to as Eddy Currents and sometimes can be used productively in certain devices.

UTILIZING EDDY CURRENTS

We have seen that when a moving magnetic field cuts a solid metal object a circulating current, or Eddy Current, will flow inside that solid metal object. These currents create their own magnetic field which oppose the magnetic fields that created

them. To demonstrate this phenomena place the 200 turn primary coil on one leg of the laminated U core and set up the two short iron bars inside the T fittings as illustrated. Hold them down in the T holders and use rubber bands to make the assembly tight and secure.

Place the metal disc and axle into the top of the T holders and position the two solid steel bars so that they are about 1-2 mm from the disc. Spin the disc to see that it does not contact the bars. (See figure 1)



Spin the disc using the axle so it rotates quickly. While it is spinning briefly connect the coil to a DC power supply delivering 6 volts. Note pre set up this so that when you have the disc spinning all you need do is switch on the 6-volt supply.

The disc will stop spinning because when the DC field is applied to the gap between the disc and the metal bars, an Eddy current flow through the disc as it spins through the magnetic field. The magnetic field around the disc created by the by the Eddy currents flowing inside the disc metal actually opposes the field in the poles. This opposing of the two fields creates, in effect, a magnetic brake to quickly slow down the spinning disc. This phenomenon can be seen in many applications in industry as magnetic braking.

SERIES AND PARALLEL TRANSFORMER CONNECTIONS

To understand the principles and importance of these concepts and the effects they have on designing or setting up a transforming device, the Induction Kit provides all the necessary components.

Varying the combinations of primary to secondary coils will give different output results and will allow you to understand the versatility of the transformer in providing the secondary output required.

Take the primary coil of 300 turns. Wind the two spare coil formers each of 100 turns and set the primary onto one leg of the transformer core and the two secondary coils to the other leg. Replace the laminated top. By applying 12 volts AC to the primary each secondary coil will give about 4 volts because 100 is one third of 300. If we added yet another secondary of 100 turns then we would have three secondary coils giving 4 volts each.

Some basic rules apply here:

When we connect secondary coils in series and in phase we add the voltages. When we connect secondary coils in series but out of phase the voltages will subtract from each other (one coil reversed in connection to the other) and we get a zero result. When we connect secondary coils in parallel and in phase the voltage remains the same but the current will double. When we connect secondary coils in parallel but out of phase the voltage will be zero but the coils will heat up quickly. Avoid this arrangement except for a brief time.

Refer to definitions page to revise some terminology: what will happen if you wind a coil of say, 50 turns and connect them to boost or buck the voltages?

An exception to the isolating transformer concept is called an Autotransformer. These are often used to “correct” supply to items using different mains supplies i.e. 110 volts AC to 230 volts AC. The output voltage is connected electrically to the primary or applied voltage and often has only one winding with a tapped output at some point of the winding or it may consist of two coils connected in series.

THOMPSONS RING EXPERIMENT

This is a classical experiment to undertake using the base transformer core. First, take the primary coil (300 turns) and place over one leg of the base laminated core, and stand the long iron bar on top of the “coil” leg. Place the supplied aluminum ring over this extended leg and connect to 12 volts AC. The ring shoots upwards and floats in the magnetic field! For different results try different voltages and then try in on DC as well.

In AC the ring acts as a secondary coil of just one turn, but that turn is actually short circuited and carries a high current which creates a very strong magnetic field around the ring, which in turn opposes the field in the primary coil. This force moves the ring from the coil until the two forces balance each other, taking into account the weight of the ring itself.

Note: Because there is a high current in the ring it may get quite hot so run this experiment for short periods. Also, note that the coil winding will also heat up so to preserve this coil and insulation avoid prolonged use.

You may like to experiment with rings of different materials you have available and also experiment with coils you wind placed on top of the primary coil. Note these additional coils should have the ends electrically connected (short circuited). Please refer to the following illustration:



BASIC AC ELECTRIC MOTOR

AC motors are used extensively in all facets of life and this part of the kit will allow you to explore the construction, assembly and principles of operation. Where motor speed is required to be very accurate these AC motors are most useful because the speed is precisely matched with the frequency of the alternating current supplied to power the motor. You may wish to expand the experiment by using the a Digital Stroboscope to check the rotor speed to ensure it is actually 50Hz.

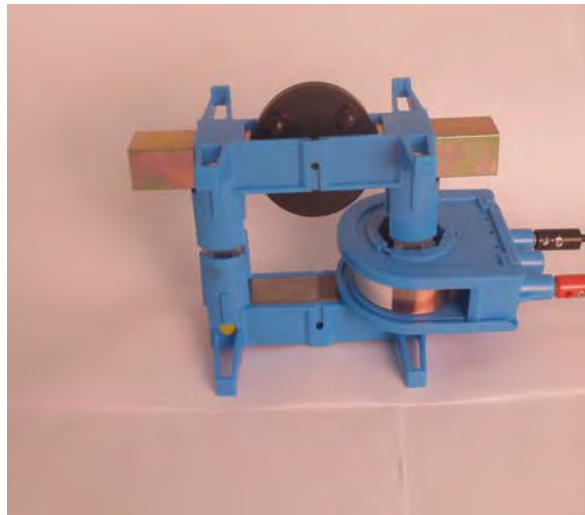
Note that if you increase the frequency, or reduce it, then the rotor will increase or fall relative to the frequency of the AC supply to the motor.

Take the 300T wound coil, the base U core, the top frame, 2 x short solid iron cores, the magnetic wheel and two 4mm leads. Also you will require 1 Power Supply. Slide the 300 turns coil over one leg of the base U core fit the top frame to the expose legs of this base core unit after having fitted the magnetic wheel carefully into the two slots provided. By moving the top frame slightly fit a short solid iron core into both sides of this frame and adjust these so that they clear the magnetic wheel by 2 millimeters.

Connect to the AC terminals of the power supply using good quality 4mm leads and apply 2 to 4 volts AC. You will need to assist the wheel to spin by turning it fairly hard with the finger to begin rotation under power: this speed should roughly equal the frequency, which is 50Hz. In commercial practice a capacitor is used to overcome the initial inertia of the rotor and the rotor and the rotor wheel will spin freely while AC power is applied.

Inside the magnetic wheel there are magnets which are alternatively attracted to the opposite pole as the AC current reverses: this all happens in microseconds and hence the magnetic wheel continues to spin.

Refer to the illustration of this experiment to assist assembly and ensure you have the unit correctly set up. You may wish use 2 rubber bands supplied to firmly locate the two short solid iron cores in a fixed position of about 2mm from the magnetic rotor wheel, and to ensure these cores maintain their relative positions as the motor will vibrate in operation.



INDUCTION MOTOR

Induction motors operate by passing an AC field through a steel rotor containing high conductive embedded bars within the steel rotor. These bars are connected in parallel at the end of the rotor. As the applied AC current moves in each direction, large circulating currents occur within the embedded bars. In turn these set up their own specific AC fields that actually oppose the original alternating field. This is in accordance with Faraday's Law of Induction.

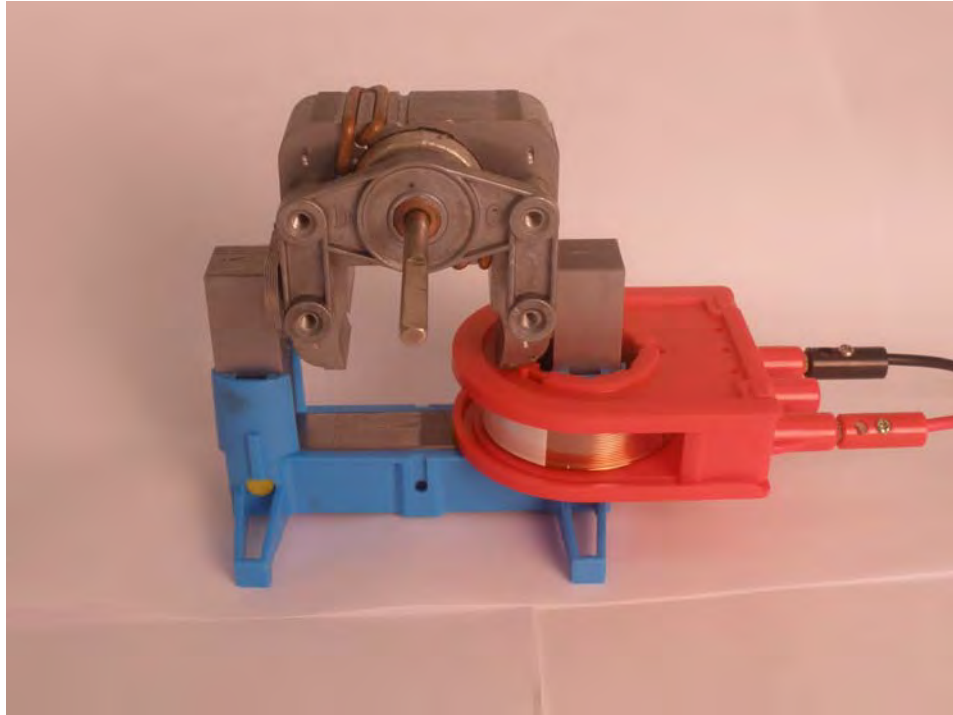
The applied field repels the embedded bars in the rotor, thereby causing the rotor to spin within the originally applied field.

Take the 300 T wound coil, the base U core, the induction motor and the small motor alignment part (this is approx. 25mm long and is made from laminated steel).

Place the 300T coil onto one leg base U core and fit the induction motor onto the base U core. Insert the alignment part with its locating tabs outwards so that the induction motor and rotor are correctly aligned.

Then, use 4mm leads to connect the terminals of the coil to the AC terminals of a 1035411 power supply and apply 12 volts AC. You may need to assist the rotor overcome initial inertia by twisting the shaft. Also, use of the rubber bands supplied to clamp the parts in place will ensure better operation and quieter running.

Whilst using this assembly carefully look at the way it is constructed and note that the very obvious copper rings form part of the iron core unit. By removing this assembly and putting it in the frame (which is correctly called a stator) in the opposite direction and then applying current to the coil, the motor will run in the opposite direction. Please refer to the following illustration.

**Warranty and Parts:**

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.