Lionet
Electromagnetic Induction Kit Cat. No 1035735

Instruction Manual

Magnetic Induction Kit Contents:

1 x Laminated Transformer Base Core
1 x Laminated Transformer Top Core
1 x Plastic Frame for Rotor and Iron Cores
2 x Plastic Frames for Short Bars and Disc Axle
1 x Iron Bar Long
2 x Iron Bar Short
1 x Primary Coil 300 turns
1 x Secondary Coil 600 turns
1 x Secondary Coil 200 turns
1 x Coil Former empty
1 x AC Induction Motor
1 x Roll Insulated Copper wire1 x Instruction Sheet
6 x Leads 2 x black/2 x Red/ 2 x Yellow
6 x Alligator clips
1 x Rotor Magnetic supplied assembled containing rotor magnets
2 x Bar Magnets
1 x Eddy Currents Disc
1 x Axle for Eddy Currents Disc
1 x Aluminum Ring Thompson's
1 x Magnetic Compass small
1 x Laminated Induction Motor Alignment piece (attached to motor

Supplementary Equipment (not supplied in kit)

The following items are required to provide appropriate power for the experiments and to measure and monitor the outcomes from performing the experiments outlined in these operating instructions:

1 x Bench Power Supply
2 - 12v AC/DC 5 A
(Serrata No. 1035411M)

1 x Lionet DC Electric Motor Kit
(Serrata No. 1035736)

1 x Voltmeter DC
Triple range 0-3V, 0-15V, 0-300V (Serrata No. 1020085)

1 x Amperemeter DC
Triple range:
0-50 mA, 0-500 mA, 0-5A
(Serrata No. 1020012)

1 x Galvanometer (Centre Reading Micro Amperemeter) -500 µA - 0 -+500 µA
(Serrata No. 1020183)

1 x Voltmeter AC 0-1V, 0-10V AC (Serrata No. 1040015)

1 x Amperemeter AC Dual Range 0-1A, 0-10A AC
(Serrata No. 1040009)

Optional
1 x Mini Digital Stroboscope
(Serrata No. 1050850)

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Lionet Electromagnetic Induction Kit

The Lionet Electromagnetic Induction Kit has been designed to allow students and teachers alike to construct, examine and experiment with the many aspects of electromagnetism such as assembling motors and transformers, measuring amperages and voltages and performing a large range of experiments.

SAFETY NOTE: THIS KIT MUST NEVER BE USED WITH MAINS SUPPLIES UNDER ANY CIRCUMSTANCES!
THE KIT HAS BEEN DESIGNED FOR USE WITH 12VOLT POWER SUPPLIES (like Serrata Model No. 1035411M) AND USE WITH OTHER POWER SOURCES WILL IRREPARABLY DAMAGE THE COMPONENTS.

LIONET SCIENCE has designed the 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 and transformer theory and practice can be clearly understood from both a theoretical and practical standpoint.

Please refer to the component part list to view the items supplied and initially to ensure all items have been included.

NOTES ON ELECTROMAGNETIC THEORY

A magnetic field is usually thought of as flowing from North to South and electrons which are negatively charged flow from the more negatively charged potential to the more positively charged potential.

This contrasts to the conventional concept where current flows from a positive potential to a negative potential and the Electromagnetic Kit embraces the latter conventional concept of electron flow.

Consider also that the North pole of a compass actually points to the South pole.

When visualizing current flow also keep in mind that (looking at a simple lamp circuit) if 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.

There is also the Right Fingers Rule for magnets ie, if current flows anticlockwise 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 or negative polarity.

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

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

CAPACITOR. This is a component which can store charge. It can be stored and released at a predetermined time...discharge occurs when the AC wave value falls and recharges as it rises... ..capacitors can be used to smooth AC current.

CHOKE in simple terms is an iron type core and a single coil fitted around it. Choke 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 to create a more efficient magnetic field... .it may be iron or ferrite which is a ceramic/iron composite.

CURRENT means the flow of electrons through a conductor as a result of a potential (Voltage) difference.

DC is a term referring to a current which flows in one direction only from positive to negative... ... it is smooth when supplied from a battery but is pulsating when supplied from rectified **AC supply**.

EMF stands for electro motive force and in simple terms begins 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 devices used, wire resistance, etc...

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

FILTER is a device connected across a DC circuit which removes the peaks so that the available current is smooth. It often consists of a large capacitor although more complex electronic circuits can achieve better results.

FLUX refers to the density or strength of a magnetic field... often used to delineate the power of permanent or electro magnets.

FREQUENCY 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. The official unit for measuring frequency is **Hertz**.

INDUCTANCE is the inductive effect or "strength" of a magnetic field and it depends upon the number of turns in a coil wound around an iron or ferrite core and the CURRENT through the coil and is measured on a scale called the Henry.

INDUCTION means the creating of a voltage in a wire coil inside magnetic field (it can be created by a magnet or even another coil of wire - the two coils are not electrically connected).

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

LAMINATIONS in AC applications strips or sheets of iron are insulated electrically from each other and are assembled so as to create an iron core but with the property of eliminating parasite (Foucault) 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.

LOSSES when transforming current certain loss will appear as a result of the winding resistance, leakage, energy dissipated in the magnetizing/demagnetizing process when using AC current to the primary etc...

MAGNETISING CURRENT refers to the current taken from the power supply by a-primary coil to magnetise 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 may not, depending upon how the secondary coils are wound, and if they are connected in series the voltages will add to each other whereas if in an opposite direction it will subtract. An interesting experiment is to examine coils wound the same direction or in opposite directions. Apply current and compare on an oscilloscope.

PRIMARY is the coil of a transformer that is connected directly to the power supply. It must provide sufficient current to magnetise the iron core as well as produce a sufficient current into the secondary winding and give the desired output.

REACTANCE when we consider DC current we think of resistance (measured in Ohms) which controls current flow in a circuit and generates energy (measured in Watts).
With AC current we still have resistance but we also have what is known as reactance. It depends upon the inductance (measured in Henrys) and the frequency of the current applied.

RECTIFICATION is a process where AC current is converted to DC. 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.

RELUCTANCE is the characteristic of a element or aloy to support a magnetic field. Metals such as Copper, Brass, Aluminium have high reluctance where Iron, Cobalt, Nickel have lower varying degrees of reluctance.

RESISTANCE this refers to the ability of a material to allow electrons to freely flow through it. Materials with high resistance (such as plastics, glass, ceramics etc…) are often used as insulators. Low resistance materials such as Gold, Copper, Silver etc… are used as high quality conductors.

ROTOR is the central component of an electric motor that moves within a commutator or field windings... ..it is often wound 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.

TAPPING is a connection point somewhere on a coil winding which is an allowance to connect a circuit at that point. In a coil of say, 100 turns, every 5th turn may be tapped. In this way several different voltages can be derived from one wound coil.

TRANSFORMER is a unit in which a number of coils of wire are coupled together by an iron core. A magnetic field produced by the primary induces a current in the secondary coil or coils. This kit will allow various transformers of varying configurations to be build and observed

VOLTAGE is the potential difference in a conductor which will produce an electrical current flow through the conductor. It can be created in a conductor when that conductor moves or rotates relative to a magnetic field cutting the lines of magnetic force. A voltage can be created by a generator or even by chemical means such as batteries, solar cells etc...

WATT - Unit for measuring electrical energy. In electric flow the energy is proportional to the Current (in Amp) and the Potential Difference (in Volts) or **W=VA**

NOTES ON INDUCTION:

When a conductor is moved in a magnetic field, such as a wire connected to a meter capable of reading very small currents, a small voltage (electro motive force) occurs (or is "induced"). Now, if you move that conductor in the opposite direction the EMF or voltage reverses. At rest the voltage will not be induced and will be nil.
In trying the above it may be the moving coil resistance in the meter (for example a 600-0-600 µA Galvanometer) that may prevent the induced voltage in the moving conductor from giving a reading so a useful idea is to make the conductor into a "coil" arrangement.
Wind a coil around any convenient former and after connection to the meter move this coil up or down around one leg of a large horseshoe magnet... ..this will usually give a reading.
Another interesting experiment is to connect one of the wound coils supplied to the meter and move a bar magnet through the coil centre. A voltage will generate as the magnet moves but will cease when the magnet stops.
Experiment by moving the bar magnet continuously up and down through the coil. Turn the coil over and note what occurs as you try different configurations. Log these and prove the basic concepts of induction.

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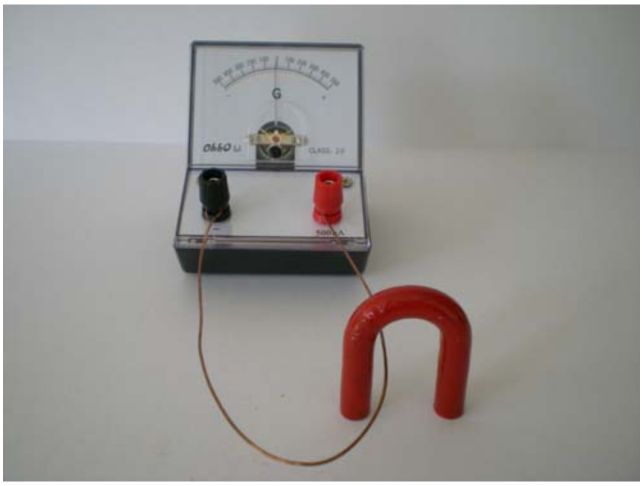
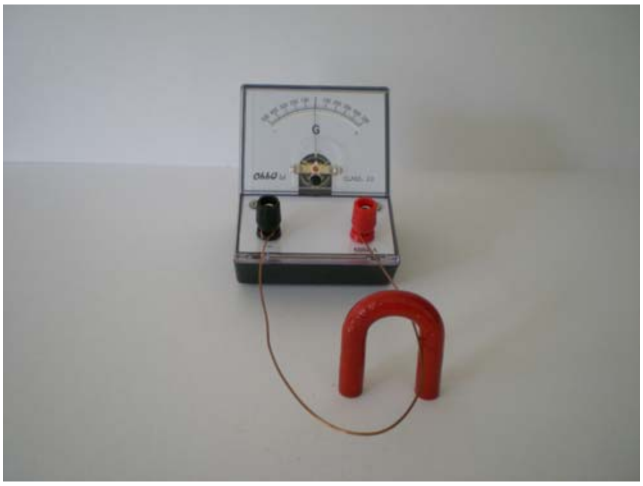
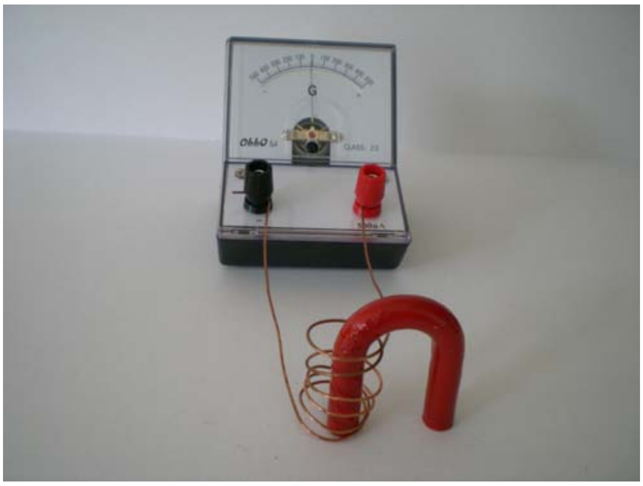
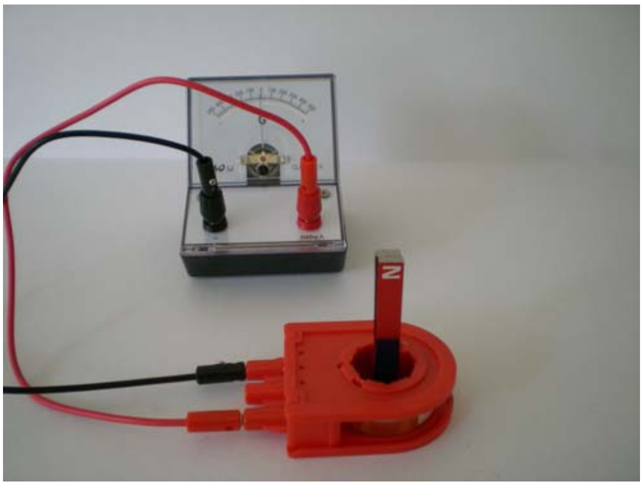
These illustrations show the set ups using meters to explore the basic principles of induction. Read the text under "Notes on Induction" and do these simple experiments as described in this section. These six experiments show the effects of magnetism on current passed through a wire in different positions and the effects when using coils and magnetic cores.

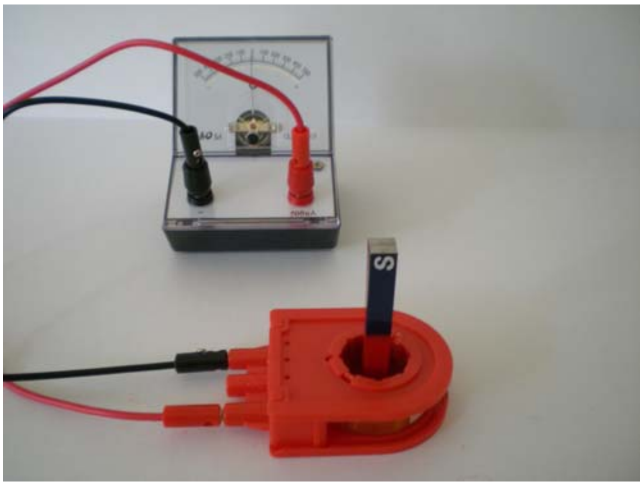
See Appendix A for information on Fleming's Left and Right Hand rules which govern "The direction of the current, the direction of the magnetic field and the direction of the EMF"

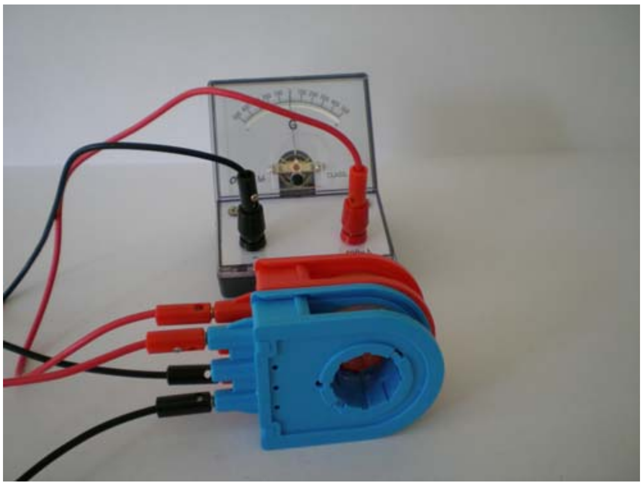












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CHANGING THE FIELD USING DC

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 a field. Apply 4 volts to one of the primary coils (300T) and insert an iron rod through the centre... .. the bar magnetises. 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 600-0-600 µA Galvanometer...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... .because we are no longer coupling the coils with air but with the iron rod the deflection of the meter will increase considerably... proving that a core makes for increased magnetic coupling.

CHANGING THE FIELD USING AC

Using the same items as the preceding section (DC) set up the two wound coils and place the iron rod in the centre ..connect to a standard bench power supply and apply 6 volts AC to one coil... the other coil connected as before to a centre reading galvanometer 600 - 0 - 600 µA. Because AC reverses its direction about 100 times a second then 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 waveform. 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

A **transformer** is a device that transfers electrical energy from one circuit to another through inductively coupled electrical conductors. A changing current in the first circuit (the ***primary***) creates a changing magnetic field; in turn, this magnetic field induces a changing voltage in the second circuit (the ***secondary***). By adding a load to the secondary circuit, one can make current flow in the transformer, thus transferring energy from one circuit to the other.

Referring to previous notes it is established that an electromotive force is produced 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 in the primary coil and the field is continually rising and falling and reversing (100 times a second with a 50 Hz supply to the primary coil) a continuous EMF is generated in the secondary coil and a useful quantity of energy is being transferred from one coil to the other.

The secondary induced voltage V_S, of an ideal transformer, is scaled from the primary V_P by a factor equal to the ratio of the number of turns of wire in their respective windings:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

By appropriate selection of the numbers of turns, a transformer thus allows an alternating voltage to be stepped up — by making N_S more than N_P - or stepped down, by making it less.

Standard bench power supply works like this. 240 volts AC are supplied to the primary coil and the secondary coil is build from several coils connected in series each of them supplying 2 Volts. 2 coils together will supply 4 Volts, 3 will supply 6 Volts etc.. These output voltages are AC but an additional component inside called a **rectifier** changes the secondary AC voltage into DC we use in the laboratory.
Because 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.
The current (amperage) depends on the thickness of the wire used.

Basic Principles of the Transformer

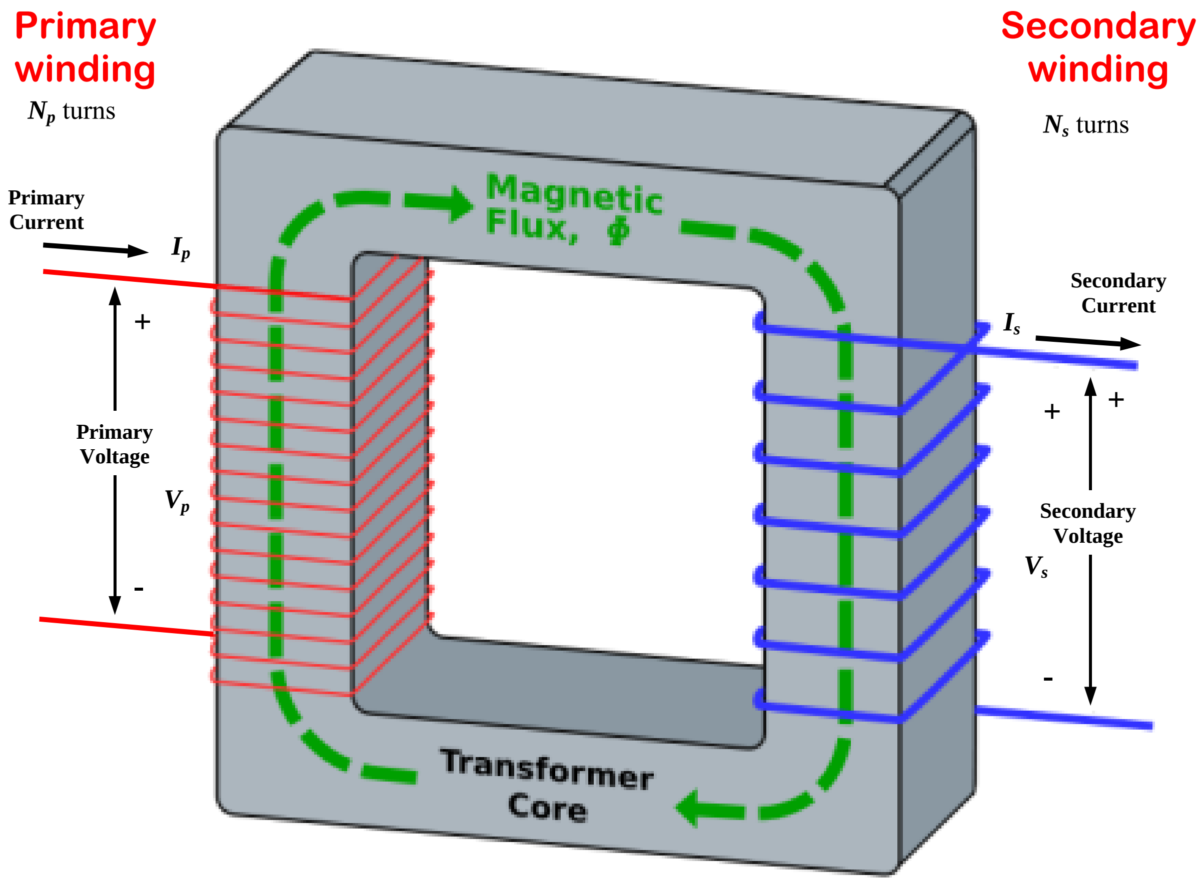
The transformer is based on two principles: firstly that an electric current can produce a magnetic field (electromagnetism) and secondly that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction). By changing the current in the primary coil, it changes the strength of its magnetic field; since the changing magnetic field extends into the secondary coil, a voltage is induced across the secondary.
See Schematic on next page!

CONSTRUCTION OF THE TRANSFORMER CORE

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

Ferromagnetic materials are also good conductors, and a solid core made from such a material also constitutes a single short-circuited turn throughout its entire length. **Eddy** currents therefore circulate within the core in a plane normal to the flux, and are responsible for resistive heating of the core material. The eddy current loss is a complex function of the square of supply frequency and inverse square of the material thickness.

Good transformer design minimises the Eddy Current loses by using laminations and 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 and you will find that 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 50 Hz AC).
Eddy Currents sometimes can be used productively in certain devices.

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 secondaries to the other leg and 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 secondaries 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 (one coil reversed in connection to the other) the voltages will subtract from each 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 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?

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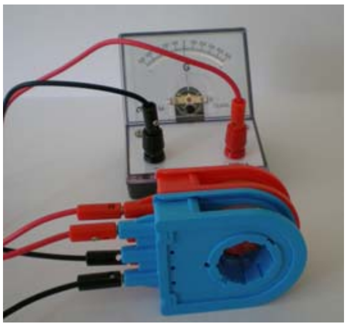
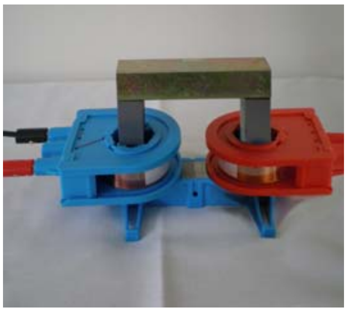
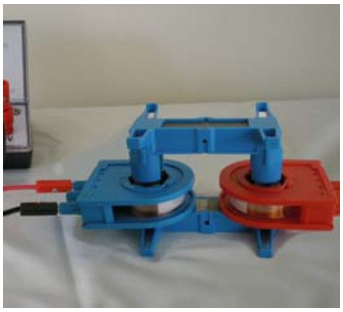
THE DC MAGNETISING CURRENT

Refer to the illustrated experimental set ups, use a fixed voltage of 6 volt DC and do comparisons of the DC current in each configuration.

NOTE: Because there will be no change in the DC current creating the magnetic field this field will have no influence on the resistance of the coil.

The configurations are as follows:
- No iron core fitted
- Only the U core fitted
- With I bar positioned on the U core
- With the laminated I core positioned on the U core.



THE AC MAGNETISING CURRENT

Alternating current is used when voltage is to be transformed and the I core will attract to the U core to make an AC electromagnet, however when separated you will hear the pulsing noise from the 100 per second pulses of the 50 Hz. Use 12 volts AC applied to the primary coil and make comparisons of this current when:
- No iron core fitted
- Only the U core fitted
- With I bar positioned on the U core
- With the laminated I core positioned on the U core.

Refer to the illustrated experimental set ups, but do not run for too long in the first two configurations.

WINDING COILS

The kit provides two wound coils: Primary of 300 turns and the secondary of 600 turns. Please exercise care if using DC with the coils as they can get very hot. A good policy is to use lower voltages from the power supply as 2,4 or 6 volts. These coils are terminated in 4 mm sockets to allow easy use of leads and connections.

A lot of interesting work can be done winding coils yourself with different numbers of turns. Simple termination is allowable or you may like to permanently terminate your windings with the 4 mm hardware supplied, or keep these as such for future use. To wind a coil slide 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.
NOTE that 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.
When working with AC if the coil is turned upside down the phase voltage will be reversed. Refer to definitions to check these principles.

WHAT METER SHOULD WE USE TO MEASURE OUR WORK

For all our basic induction experiments it is best to use sensitive, good quality DC Voltmeters (Cat. No. 1020085), DC Amperemeters (Cat. No. 1020012) and Galvanometers (cat. No. 1040012) which are needed to detect and measure small currents that flow as conductors are moved in a magnetic field. With the transformer experimental work you will require AC meters such as the cat. No. 1040015 AC voltmeter (0-1/0-10 Amps AC) and an AC Amperemeter such as the cat. No. 1040009 (0-1/0-10 Amps AC). Analogue meters are best as they are simple to setup and can measure trend or gradual movement whereas digital types do not and may prove more confusing to students. In some experiments there is a need for an additional meter where numbers of secondary coils are used.

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. In order to "clamp" the two cores together you can use strong elastic bands over the "arms" of the assembly which will ensure good continuity and prevents air gaps between the top and bottom laminated sections and consequently will minimize magnetic leakage.

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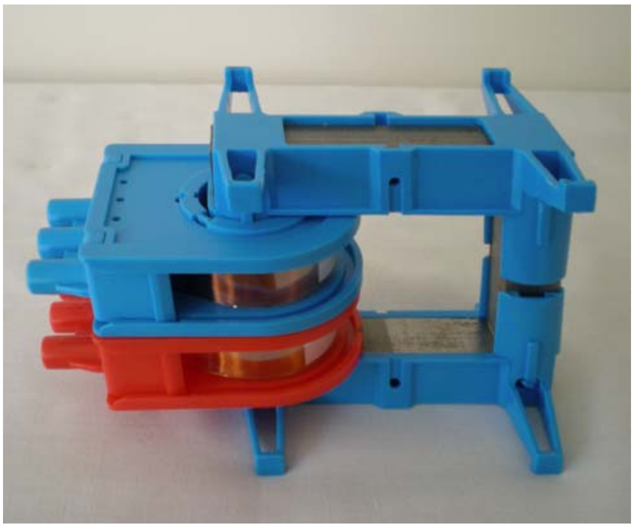
Apply 12 volts AC to the primary coil (300 turns coil) and using an AC voltmeter measure the output voltage from the secondary coil. Using the previously explained calculations work out the secondary or transformed voltage.
You can vary the combinations like placing both primary and secondary coils on the same leg and measuring the output or reverse the secondary and measure again. Soon you will understand the effects of adding, subtracting, doubling or cancelling on the output voltage.



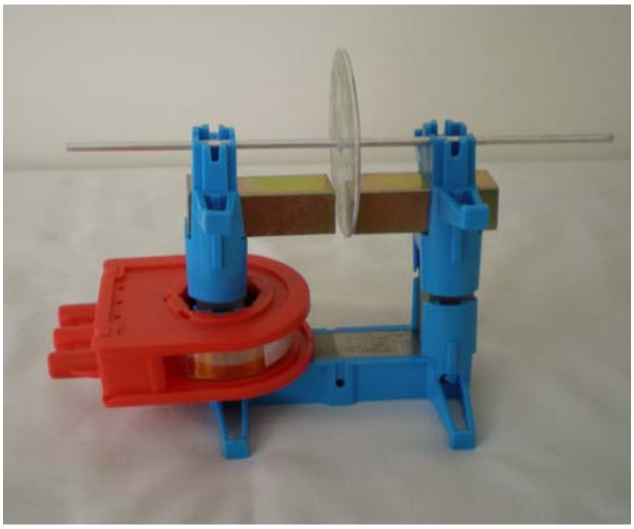
Take measurements of the current (amperage) using the galvanometer or sensitive ammeter. To check for magnetic leakage use the small axle used with the Eddy current disc and hold it close to the corners of the transformer core. If leakage is present you will feel a small vibration in the axle. You may also like to place shims of paper between the tips of the U core and the I core (thus creating an air gap) and check for leakages again. Use your voltmeter to check at different primary voltages and at 12 volts AC. Check for differences in the coil magnetizing current.

ILLUSTRATED EXPERIMENTAL ARRANGEMENTS USING THE KIT

The following illustrations show how to set up the various induction experiments.
These experiments are simple to arrange using the components in the Induction Kit and in almost all cases involve using a DC Voltmeter, a DC Amperemeter, an AC Voltmeter, an AC Amperemeter and of course the centre reading Galvanometer or centre reading micro Amperemeter. Following the instructions in the text you will see that we measure voltages and amperages using identical set ups, but substituting different meters to obtain either voltage or amperage measurements.

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.



Now spin the disc using the axle so it rotates quickly and whilst 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 a magnetic field is applied, an Eddy current flows through the disc as it spins through the magnetic field. The magnetic field around the disc created by the Eddy currents inside the metal of the disk actually has opposite poles to the poles of the outside field. This creates, in effect, a magnetic brake to quickly slow down the spinning disc. This phenomena can be seen in many applications in industry and is known as Magnetic Braking.

THOMPSONS RING EXPERIMENT

This is one of the classical experiments using the base transformer core.
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 leg. Place the supplied aluminium ring over this extended leg and connect to 12 volts AC. The ring shoots upwards and floats in the magnetic field.
Try different voltages and then try it 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 forces moves the ring from the coil until the two forces balance each other, taking into account the weight of the ring itself.

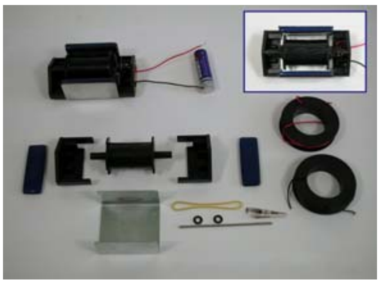
***Note:* Because there is a high current in the ring it may get quite hot so run this experiment for short periods.**

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)!

ELECTRIC MOTORS



To increase the versatility of the Lionet Induction Kit and extend the investigations into electric motors there is available a small self assembly DC Electric Motor (Cat. No. 1035736).

This kit allows a student to wind their own motor, set it up and examine and gain understanding into the construction and principles of operation.

NOTE: You may need to spin the motor to get it rotating.

BASIC AC MOTOR

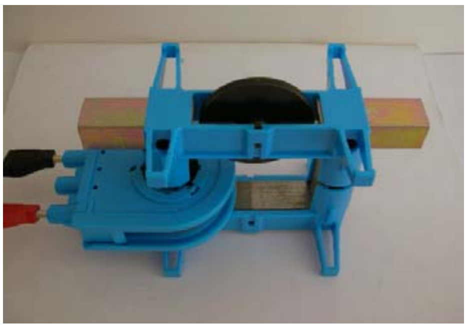
An AC motor is an electric motor that is driven by an alternating current. It consists of two basic parts, an outside stationary stator having coils supplied with AC current to produce a rotating magnetic field, and an inside rotor attached to the output shaft that is given a torque by the rotating field. There are two types of AC motors, depending on the type of rotor used. The first is the **synchronous motor**, which rotates exactly at the supply frequency or a submultiple of the supply frequency. The magnetic field on the rotor is either due to current transported with slip rings or a permanent magnet. The second type is the **induction motor**, which turns slightly slower than the supply frequency. The magnetic field on the rotor of this motor is created by an induced current.

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 AC **synchronous motors** are most useful because the speed is precisely matched with the frequency of the alternating current supplied to power the motor.

To construct and assemble **synchronous motor** take the 300T wound coil, the base U core, the top frame, 2 x short solid iron cores, the magnetic wheel and two 4 mm leads. Also you will require 1 x 1035411 Power Supply. Slide the 300 turns coil over one leg of the base U core fit the top frame to the exposed 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 millimetres. Use 2 x rubber bands supplied to firmly locate the two short solid iron cores in a fixed position of 2 mm from the magnetic rotor wheel and to ensure these cores maintain their relative positions as the motor will vibrate in operation.

Connect to the AC terminals of the power supply using good quality 4 mm leads and apply 2 or 4 volts AC.

Refer to the illustration of this experiment to assist assembly and ensure you have the unit correctly set up.



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 50 Hz. In commercial practice a capacitor is used to overcome the initial inertia of the rotor and the rotor wheel will spin freely whilst ever AC power is applied. Inside the magnetic wheel there are magnets which are attracted to the opposite poles and as the AC current reverses continuously the magnetic wheel continues to try to “catch up”. If you can spin it fast enough it will synchronise with the reversing AC field and the disc will continue to spin as a motor. This is called a synchronous motor as the speed is synchronous with the frequency of the power supply. These motors are common especially in clocks and other devices where constant speed is critical. The speed will be a function of the frequency of the AC supply and in this case 50 Hz equates to about 1500 revolutions per minute.

You may wish to expand the experiment by using the 1050850 Digital Stroboscope to check the rotor speed to ensure it is actually 50 Hz.

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

INDUCTION MOTOR

An **induction motor** is a type of AC motor where power is supplied to the rotating device by induction. An electric motor converts electrical power to mechanical power in its rotor (rotating part). In the AC motor this power is induced in the rotating device. An induction motor can be called a ***rotating transformer*** because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Induction motors are widely used, especially polyphase induction motors, which are frequently used in industrial drives.

Induction motors are now the preferred choice for industrial motors due to their rugged construction, lack of brushes and - thanks to modern power electronics - the ability to control the speed of the motor.

Principle of operation and comparison to Synchronous motors

The basic difference between an induction motor and a synchronous AC motor is that in the latter a current is supplied onto the rotor. This then creates a magnetic field which, through magnetic interaction, links to the rotating magnetic field in the stator which in turn causes the rotor to turn. It is called synchronous because at steady state the speed of the rotor is the same as the speed of the rotating magnetic field in the stator.
The induction motor does not have any supply onto the rotor; instead, a secondary current is induced onto the rotor. Conductors in the rotor induce a current as the rotating magnetic field created by the stator windings sweep past them much in the same way as in a transformer. This current in the rotor conductors will therefore induce a magnetic field which will interact with the rotating magnetic field in the stator and the rotor will turn. For this to happen, the speed of the rotor and the speed of the rotating magnetic field in the stator must be different, or else the magnetic field will not be moving relative to the rotor conductors and no current will be induced. If this happens, the rotor slows slightly until a current is re-induced and then the rotor continues as before. This difference between the speed of the rotor and speed of the rotating magnetic field in the stator is called ***slip***. It is unit less and is the ratio between the relative speed of the magnetic field as seen by the rotor to the speed of the rotating field. Due to this an induction motor is sometimes referred to as an **asynchronous machine**.

Construction

The stator consists of wound 'poles' that carry the supply current that induces a magnetic field in the conductor. The number of 'poles' can vary between motor types but the poles are always in pairs (i.e. 2,4,6 etc).
There are two types of rotor:

- Squirrel-cage rotor
- Slip ring rotor

The most common rotor is a squirrel-cage rotor. It is made up of bars of either solid Copper (most common) or Aluminium that span the length of the rotor, and are connected through a ring at each end. The rotor bars in squirrel-cage induction motors are not straight, but have some skew to reduce noise and harmonics.

Assembly

Take the 300T wound coil, the base U core, the induction motor and the small motor alignment part (this is approx 25 mm 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 4 mm 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. Use of the rubber bands supplied to clamp the parts 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 in the opposite direction and then applying current to the coil the motor will run in the opposite direction.

Any suggestions for additional experiments and/or different uses of this Electromagnetic Induction Kit are welcome!

Appendix A

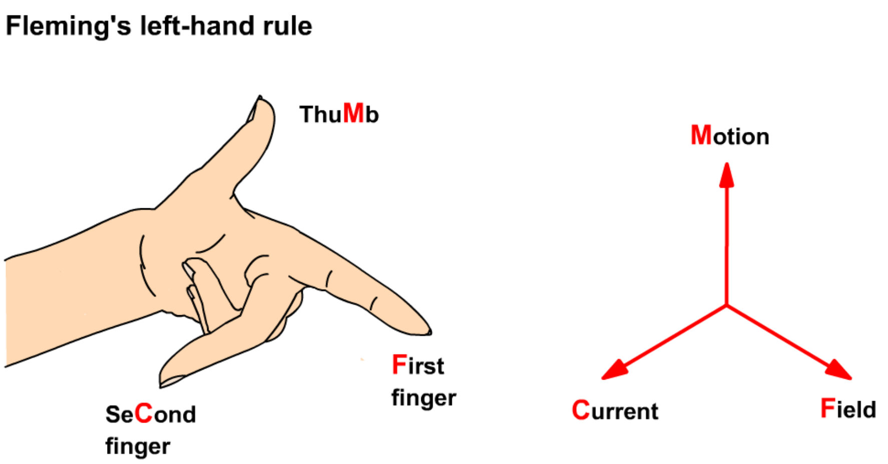
Fleming's left-hand rule:

Fleming's "left-hand rule" can be used to work out the direction of the force when a current flows in a magnetic field.

The direction of the current, the direction of the magnetic field and the direction of movement are at right angles to each other. The way to remember how the wire moves is by using "Fleming's left-hand rule".

Hold your left hand as shown in the picture. Follow these three steps to learn how to predict which way the wire will move:

1. Rotate your hand so the **F**irst finger is in the direction of the magnetic **F**ield
2. Point your se**C**ond finger in the direction of the **C**urrent.
3. Your thu**M**b is now pointing in the direction of the **M**ovement.



Fleming's left-hand rule is used for motors.
When the motion and the magnetic field directions are known, as in the case of a generators the Right Hand Rule using the same markings for the fingers, is used to find the direction of the current flow.