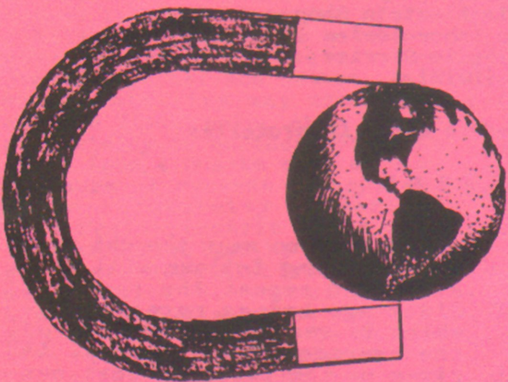
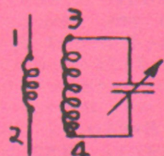
another MRL Handbook... HB-7

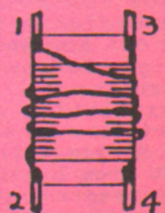
EXPERIMENTS WITH Magnetism *and* COILS



C O N T E N T S.

By Elmer G. Osterhoudt.





by

Elmer G. Osterhoudt

"With Radio since 1915," including:

Radio Operator, R.C.A. Marine Service
Radio Mechanic, Maximum, U.S.N.
Technician, Electrical Products Corporation
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Modern Radio Laboratories
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F O R E W O R D

We Old Timers can barely realize that Oersted, Faraday and Gauss made their Electro-magnetic discoveries less than 150 years ago.

Arthur Brisbane once noted Editor for Hearst, said:"If you analyse one drop of Sea water you know the contents of the Ocean." While it takes a smart man to state things simply- this may be fairly true chemically. However, there are millions of things in the Sea that cannot be detected in this drop of water.

Similarly, if we understand Magnetism, current and Electron flow in primary and secondary circuits, and their compelling & obstructing forces - we cover the most important principles of Radio and Electricity.

The more experienced may feel they know this subject well. But do you remember sitting in on some beginner Radio class and find out how much you can learn that you had passed over? Every Instructor has a different way of explaining and associating principles. In my own case, with over 40 years in Radio, I learn a lot from beginners. Even with their meagre experience they can "dig out" a lot of interesting material that I have missed.

But, as they grow up, they, too, will find their Cranium can absorb just so many thought waves, and young fellows will come along and repeat the process. Older age brings experience - which is really a summation of the average pros and cons. It gives us the power to sort out the essentials and use shortcuts and, as a result, we forget a lot of the simple principles.

In this Handbook we hope to "lay it on the line" as far as simple explanations are concerned. If you refer to many texts you can easily find what is the pet subject of any Writer. He'll go off on a tangent into some field and do a thoro job of putting it down. Other more essentials, that we may require, may be passed over lightly. It so happens that Magnetism and current flow are taken for granted, altho we find much yet to be explained. It is an interesting, as well as a big subject as evidenced by the mass of material we have gone thru. So much of it is surrounded by Engineering terms that are not grasped by Fans like us. Our mission is to "dig it out and serve gently!"

Rules in Electricity are good day and night. They will always seem the same, too, if we learn the principles that take the mystery out of this interesting field of Radio and Electricity.

1. ELECTRICITY & MAGNETISM.

The four principal things in Radio receivers are the coils for inductance; condensers for capacity; resistors for resistance and tubes, or semi-conductors for rectifiers or amplifier stages.

There are several forms of Electricities. Static comes from friction. Voltaic Electricity is caused by chemical action within a battery. Thermal is produced when two opposite metals are placed together and heated. Animal Electricity may come from certain fish, eels, etc. Piezo-electricity is another form that comes from a Quartz crystal when pressure or current is applied. Photo-electricity is derived from Photo-electric cells when they are energized by light. You get Thermionic Electricity from emission of electrons from a heated tube filament or cathode. Electricity may also be formed with breaking up of water drops. There are others but our main concern in this Handbook is with Magneto-electricity which concerns coils, magnets, dynamos, generators, etc.

We do not exactly know what Electricity and Magnetism are but we know how to produce and control them. We do know that Electricity produces Magnetism and Magnetism produces Electricity. They are two distinctly different things and act differently in the circuit. Wherever there is a current of Electricity there is also a magnetic field. This magnetic principle is used in all coils, motors, dynamos, magnets, etc. and even in deflection of cathode rays in Television. Electro-magnetic waves make up most of the transmitted waves of Radio stations, which vary in length from 18 mi. long to 1/250th of an inch. The Broadcast band waves may run 656 to 1969 feet in length. Even the Cyclotron depends for its operation on the rapid movement of these waves at high frequency. It covers the Electromagnetic spectrum from Audio thru Gamma rays.

2. CURRENT & ELECTRON FLOW.

If one goes back a number of years they will find many authorities claiming that Electric current flows from positive to negative. With a battery they even say it flows from positive to negative thru a wire and from negative to positive within it. Lately it has become good theory to claim Electron current flows from negative to positive. This latter is called the "electron drift." Some even claim, that for practical purposes of Electricity, it goes from positive to negative. One writer, as an easy out, says:"whichever pole we call positive, the opposite is negative!"

From the Electron theory it is now considered that positive protons do not move - only negative electrons move from negative to positive, as they reach a fair balance. Positive protons cannot travel thru a metal but only negative electrons can move around from place to place.

Edison proved there was a current flow from filaments of vacuum tubes as they gave off negative electrons, similar to the evaporation of water. He did not realize he had the principle of the modern vacuum tube in his hand. This is known as Thermionic emission as they give off Thermions. Any substance, when heated sufficiently, will give off electrons. If a Platinum heater is coated with an oxide of Barium or Strontium its emission is greatly increased. When a Thorium salt is added to a tube filament it is called a Thoriated filament.

This thermionic emission can be tied in with the Electron current flow theory. DC filaments give off electrons when heated. If we put AC on them we will get a strong AC hum in the set. So the AC type tubes put a Cathode around the filament - the latter is then heated like an electric iron. DC can also be used on AC tubes- as you find in auto sets. As a result, the Cathode gives off steady negative electrons.

When heated sufficiently these negative electrons are attracted to the positive plate and electron current now flows from the ground side to the plate over this thermion path. De Forest came along and put a grid in the diode vacuum tube (Fleming valve it was called), between filament and plate. By interruption of this electron flow by this grid we can now "trigger" the value of the flow to plate at will. A tiny signal is then amplified in the phones. The point, we are proving, is that electron current flows from negative to positive.

3. ELECTRON THEORY OF MAGNETISM.

They used to believe that metals contained magnetized molecules. Now they think they are spinning electrons - each acting as a tiny, whirling electrified ball within the atom. The more magnetized a material the faster they spin. It is known that a moving negative electron produces an Electric current and that an Electric current produces a magnetic effect. It is also believed that magnetic substances have more electrons spinning in one direction than the other, in order to give them polarity. In a non-magnetized material the atoms are thought to be haphazard, but in a magnetic material they are arranged with N and S poles adjoining. If the external field is reversed sufficiently the atoms are re-arranged. If enough magnetization occurs the material becomes saturated.

4. EARTH or TERRESTIAL MAGNETISM

Magnets are divided into three classes. (1) Natural magnets as Lodestone. (2) Permanent magnets as bars of hardened steel that have been magnetized. (3) Electro-magnets which are soft iron bars wound with a coil of insulated wire. Coils also come under this category except most of them use air or powdered Iron for cores.

Lodestone, Magnetite, Iron oxide (Fe_2O_3) was used by Norse navigators and Chinese as early as 218 A.D. They mounted it on a float in water and used it as a compass. Not all Magnetite is magnetized in the natural state. "Magnet" was named from Magnesia in Asia Minor, where in 585 B.C. it was found already magnetized. Before the days of Queen Elizabeth people thought the North Star attracted the compass. Columbus' compass was a magnetic needle in a cork floating in water.

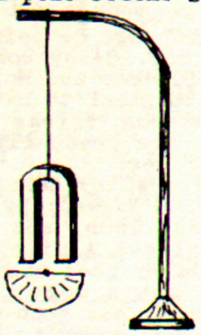
We cannot discuss magnets unless we mention the Earth as being the largest magnet of all. The Earth's magnetism is estimated as extending 4000 miles from land. We can call this magnetic flux, as you'll see later. These lines of force flow out North and back down thru the air to the South pole and up thru the magnetic core of the Earth. As with other magnets the attraction is greater at the poles and it is said the lines of force are closer together at the North pole.

If you are at the pole and you hold a tiny horseshoe magnet near a compass needle - the latter will deflect it away from the pole. But, over a long distance the pole is stronger. It may be compared to a strong Radio station that you can hear hundreds of miles. On the other hand, a 1000 watter will blast your speaker when near it - but it won't carry 100 miles away. The field becomes weaker inversely as the square of the distance. A field 4 times the distance away will be 1/16th of the power of the station - or, in this case, the magnet or pole.

As the magnetic pole is 1400 miles away from the actual North - we get a different reading in different locations. This difference ic call **Declination.** Declination in New York City is 11½ deg. West. In San Francisco it is 18 deg. East. A slight change occurs after long periods and during sun spots. It can be estimated in advance. When Columbus sailed West his compass

began acting up and scared the sailors. They did not know about declination then - and sailors always were superstitious.

Which is North? We know that a South pole attracts a North. So, what pole of a needle is pointing toward the North? It is usually agreed that it is called the North pole - which now makes our North pole become South. Hi.



4-1. Gauss' Pendulum.

4-1. **Experiment.** Gauss Pendulum. An interesting experiment can be performed if you own a large horseshoe magnet. Suspend it on about 12" of fine silk thread, above a table. Lay a protractor under it to tell the angle of swing. Apparently any angle it is started will be kept as long as it is suspended. A light magnet may also be placed on a cork in water but probably the swing wouldn't be as pronounced as the fine thread - due to less friction. We started it at 7½ deg. off center and it returned every time. Then at 55 deg. off center and it returned each time to its starting point.

There is also a slight side vibration of approximately 1 sec. we cannot explain. The principle shows that the two poles have equal strength, which is true of all magnets. The North pole pulls it back to center and the South pole pushes it back again. If they were uneven in pull - it would stop swinging. This can work in any DC magnetic field as well as that of the Earth.

Magnetic storms produce the Aurora borealis, Northern or Polar lights. In the South they have Aurora australis, or Southern lights. Some may run for but a few minutes - others for days. These storms may swing the needle 45 deg. off scale in Polar regions. It has little effect at the Equator. However, as Radio signals go the shortest way, which is usually over the Poles, - the Auroras greatly affect transoceanic reception. Many telegraph and telephone lines R affected nearer the Poles. Sun spot activity has been increasing lately - and long distance reception has improved. RCA Engineers claim that Sun spots help DX reception. No doubt the magnetism has something to do with this condition.

The Aurora theory is that the Sun gives off electrons, again - as any incandescent body - and they pass to the Earth thru a vacuum of outer space, or rarified gas. Cathode rays are visible in a vacuum, as surrounds the Earth's atmosphere, the same as we see in a TV picture tube. Cathode rays are likewise deflected by the magnetic poles, like the magnetic deflection circuit in our TV tube.

As a little experiment, place a magnet near an Electric light. If AC- the filament will vibrate 60 times per second. If DC it will just be pulled over.

5. PERMANENT MAGNETS.

More has been learned about magnets in the last 10 years than 20 centuries before. There are 3 classes of magnetic substances used for cores. They are Diamagnetic, Paramagnetic and Ferro-magnetic. Diamagnetic and Paramagnetic are really considered non-magnetic in general.

Diamagnetic substances are less than unity and assume a crosswise position to the direction of the magnetic field. Some of these materials are Bismuth, Antimony, Copper, Silver, Zinc, Sulphur, Mercury, Gold, Water.

Quartz, etc. If these are placed in a strongly magnetized field they become weakly magnetized. Bismuth, with a permeability of 0.9998 is the strongest.

Paramagnetic substances are greater than unity and align themselves with the field. Some of these are Oxygen, Manganese, Chromium, Platinum, Aluminum. They also become weakly magnetized in a strong field, but lay with the field instead. Platinum with a permeability of 1.00002 is the strongest of this type.

Ferromagnetic substances are very much greater than unity. Some of this type are Iron, Cobalt, Nickel, and many alloys. Iron is the best magnet; Cobalt the least. But, in combinations, as alloys, it all changes. Cobalt-steel magnets are about the best, but as Cobalt is expensive - not over 35% is used. A Canadian 5¢ piece will be attracted to a strong magnet, due to its Nickel content. But a 5¢ U.S.A. will not as it contains too much Copper which would neutralize its magnetic properties.

By using fine magnetic material super-magnets are now made. Fine Iron dust runs about a billion billion to a pound. Super-magnets are now made by G.E. of Manganese and Bismuth embedded in plastic. Abroad they use Barium and Iron oxides.

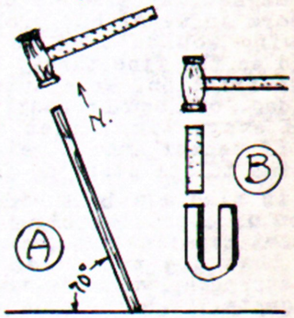
If a permanent magnet is heated to a cherry red it will lose its magnetism. Also if it is jarred very hard. Both tend to dis-arrange the atoms so they go back to haphazard formation. If a heated bar cools in a magnetic field it becomes magnetized permanently. A bar of steel may also be permanently magnetized if it is placed inside a coil energized by DC. **Residual** magnetism is that which remains in a magnet, even in a soft iron bar there is always some left. Permanent magnets become weaker all the time, but good ones retain their magnetism for a long time. This is called **Retentivity.** Magnets may be aged by heating to 100 deg. C for 12 hrs. when they become more permanent.

Alloys. By combining magnetic and non-magnetic substances in the right proportions metallurgists have been able to develop some very strong magnetic material. This is similar to adding "impurities" to Germanium to increase its sensitivity. Another good instance of an Alloy causing a major change is Wood's metal where Lead, Tin, Bismuth & Cadmium, with highest melting point of 327 deg. C. being dropped to 71 deg. C. by combining. Also when Silicon and Molybdenum are added to Steel to harden it. Nature has many tricks but our Scientists are gradually catching up with her!

One **Alnico** alloy contains 12% Aluminum; 20% Nickel; 5% Cobalt, and the rest Iron, and was one of the earliest Alnico steels. Alnico usually goes under Alloy #111, but now a more powerful one, Alnico V, has been created. Alnico has the power to hold its magnetism almost indefinitely. Alnico is now used in most headphones, speakers, magnets, etc.

Permalloy is another core material of 80% Nickel and 20% Iron. There is a whole series of Permalloys developed by the Bell Laboratories.

Heusler Alloys are of non-magnetic materials, as Copper 60%; Manganese 24%; Aluminum 16%. If you study up on Alloys you will find it very interesting.



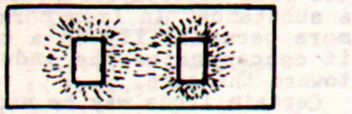
5-1. Magnetizing by Jarring Atoms.

5-1. Experiment. If a soft Iron bar is placed in a North & South position (A) and slanting a little as shown, and tapped with a hammer, it becomes slightly magnetized. As evidence it can be checked with a compass or magnetic needle. Laying it down, and tapping again may remove its magnetism. So do not over-jar a magnet. (B) Bar may be held near a magnet and tapped with the same results.

If near a stream, run a magnet thru the sand and see how much Iron you can pick up.

Never hold a magnet close to your watch - or it will cause it to lose time as hairspring will become magnetized and "sticky." I've had a lot of trouble around a bench where speaker fields, etc. would magnetize my watch - causing it to stop eventually.

6. LINES OF FORCE & PULL.

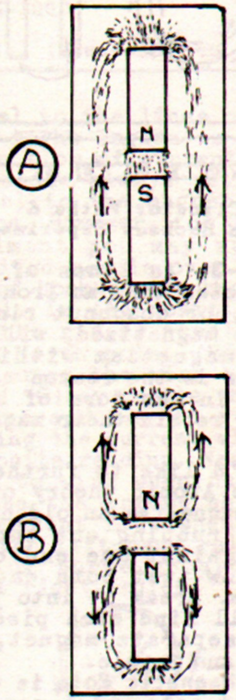


6-1. End of Horseshoe Magnet.

6-1. Experiment. Place a piece of paper over the ends of a magnet, bar or horseshoe. Throw some filings from the emerywheel on top of the paper and watch how the lines of force form. You can also lay it alongside the horseshoe magnet and note formation in different positions. If you pull it back and forth you will find many of them jump to the ends of others. The attraction of small particles for each other is about as great as the magnetism in the magnet. Each N pole of a particle will adhere to the S pole of its neighbor.

If you consider all the lines of force together it is called **Flux. Flux density** is the number of lines of force passing thru a line drawn perpendicularly to the field path. Flux density determines the strength of the field and magnet. Magnetic flux around wires consists of circular lines of force around the wire in a clockwise direction (if you figure Electron current flow). Larger wire has a larger field. Flux density is always greater than the field intensity - and no two magnets are alike.

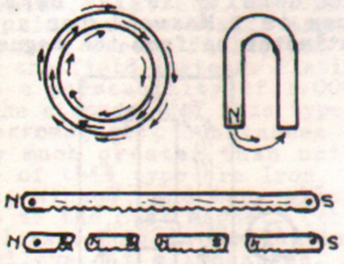
The unit of magnetic flux is the **Maxwell.** and represents one line of magnetic flux. Unit of flux density is the **Gauss.** A Gauss is 1 Maxwell per square centimeter up from the magnet.



6-2. Combining & Opposing Fields.

6-2. Experiment. You can get a good picture of the lines of force if you have two magnets. Bar magnets are preferred but a couple of horseshoe magnets will work. At (A) place them about ½" apart- or farther if the attraction is too great. Place a piece of cardboard over them and throw some Iron filings over the whole cardboard. You will find the outer fields combine and tend to straighten out.

At (B) if you place them so they oppose each other the lines of force do not combine. The lines of force form at the North pole and go thru the air to S. In any of these experiments, in case you drop a lot of filings on the magnets - use a rag to wipe them off.



6-3. Circular Paths & Broken Hacksaw Experiment.

Fig. 6-3. As lines of force travel easier thru an Iron path, a Toroid, or doughnut ring, if it can be magnetized, will keep all its magnetism within the ring. This is the reason magnets are made in the form of horse-shoes- to retain their magnetism longer.

If you'd like to further impress the Atomic theory of magnetism- magnetize an old hacksaw blade by rubbing one end of a magnet against one end of the blade. Now test both ends for magnetism. Break it into pieces and you'll find each piece becomes a separate magnet, each with a N and S pole.

A Unit Magnetic Pole is defined as that pole which repells a similar pole at a distance of 1 cm. of 1 Dyne. A Dyne is the force which, acting on a mass of 1 gram for 1 second, would give it a velocity of 1 cm. per sec. The force between two poles acts along the line adjoining the poles. Therefore, a North pole is acted on by two forces - one of repulsion and one of attraction. In the path between N & S poles there are different degrees of attraction as can be seen by setting a compass needle at different positions.

Attraction or repulsion is inversely proportional to the sq. of the distance between them. For instance, if the distance is increased 4 times, we get 1/16th of the attraction, or repulsion when they are together. Therefore, headphone and speaker gaps are made small as possible to develop the most pull. If too far away from the pole pieces the phones become weak. Check Ur phones and see if diaphragms can easily be bent to the poles.

7. PERMEABILITY, RELUCTANCE, SATURATION.

Permeability is the ability to permeate, or soak thru. It is the ease with which lines of force can flow thru a magnet as compared with air, which is rated as 1.0. It may be defined as the flux-multiplying property of a substance. An Iron core gives more permeability to a coil as it concentrates the inductance toward the core.

Certain Irons may be magnetized more easily than others, but their magnetization finally ends at a saturation point. Soft Iron cores change polarity easily with a change in direction of current of coil around it. Laminated cores are used in transformers for AC. It means "in layers." But for DC - solid Iron cores are used. A laminated core can become magnetized and demagnetized easier than a solid core as it cuts down Eddy currents which cause heating and reactance to AC flow.

Reluctance is the opposition to the flow of lines of force. It means unwilling; slow to act. Reluctance in magnetic circuits is analogous to resistance in an electrical current circuit.

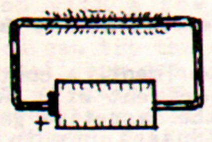
Magnetic saturation is the point where no more magnetizing can be done. If you place weak magnets across a powerful horseshoe magnet and leave it for a few days - they will be saturated as far as practicable. (See Handbook No. 1 on phones.)

	Permeab. Maxwells	Flux Den. Gauss
Cobalt	1170	3K
Iron-cobalt Alloy (Co 34%)	13K	8K
*Heusler Alloy (Cu 60%; Mn 24%; Al 16%)	200	2K
Iron, purest commercial annealed	6-8K	6K
Nickel	400-1K	1-3K
Permalloy (Ni 78%; Iron 21%)	over 80K	5K
Perminvar (Ni 45%; Fe 30%; Co 25%)	2K	4
Silicon steel (Si 4%)	5-10K	6-8K
Steel, cast	1500	7K
Steel, open hearth	3-7K	6K

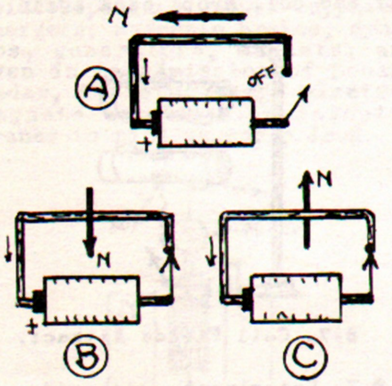
*Heusler Alloys are non-magnetic. K-1000

7-1. Permeability of Magnetic Materials. (Hausmann)

8. ELECTRICITY PRODUCES MAGNETIC FIELD. ELECTRO-MAGNETS.

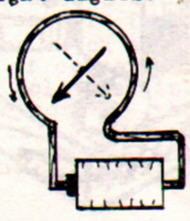

8-1. Electric Wire Dipped in Filings.

8-1. Experiment. In 1819 Oersted discovered that an Electric current is always surrounded by a magnetic field. Hook a #14 wire across a drycell and lay it in some Iron filings and see how they cling.

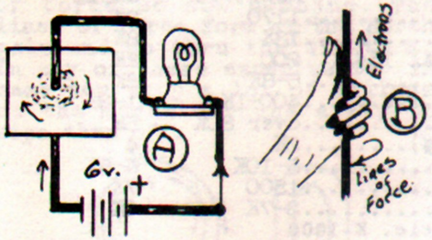


8-2. Oersted's Experiment.

8-2. Experiment. In 1820 Oersted found a single wire would control a needle by setting it parallel to the lines of force, and at right angles to the wire and the flow of current. A compass needle always sets itself parallel to the magnetic lines of force. However, for Oersted's experiment you may suspend a magnetized needle over a single piece of hookup wire hooked to a drycell. In (A) position "off" align the rig so needle points to the North pole. (B) Lay the needle over the wire and close switch. (C)Lay needle underneath the wire and see it reverses. Reversing the current also gives an opposite reading. Needle also sticks to wire when current is on. Note the arrows show Electron current flow when you are using the left-hand rule (8-4). Lines of force go around the wire at right angles.

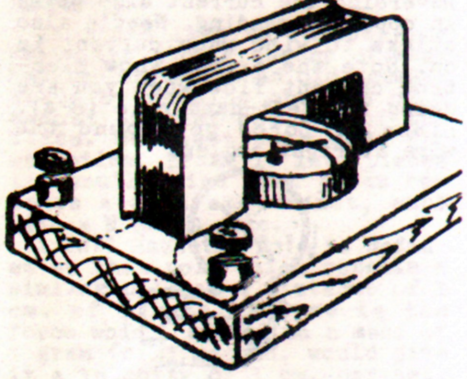

8-3. Field of Looped Wire.

8-3. Experiment. Taking Oersted's experiment above, we form the wire into a loop instead of the straight wire. You will find the needle now points in a 45 deg. angle. Place it below the loop and it will point in the dotted position. The more turns in the loop the easier it will swing to one side.



8-4. The Left-hand Rule.

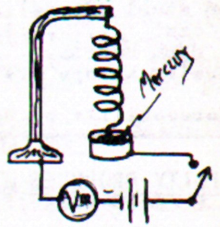
8-4. Experiment. Push a #12-14 wire up thru a cardboard. Hook it in series with any lamp for a resistance, a 6 v. storage battery and a switch. Scatter some Iron filings around on the cardboard and push the switch. You will see how lines of force form around the wire. We are using the left-hand rule with Electron current going from negative to positive as shown at (B). If you prefer to say Electric current flows from positive to negative then use the right-hand rule. Reversing the current shows a change in Iron filings.



8-5. Making a Galvanometer.

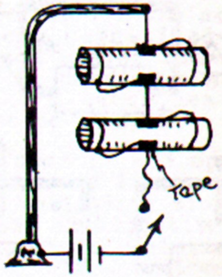
8-5. Experiment. A sensitive Galvanometer is a handy thing around the shop. Drawing shows how it is made. Rig up a cardboard form and fit it into a wooden base. Wind 200, or more, turns of #32 enameled wire and bring out to binding posts. Obtain a good sensitive compass to mount as shown with glue. For experiments you may place needle so it points to the North - in any position to use as a null.

Electro-magnets. A solenoid, or coil, is an electro-magnet, even tho it has an air core.



8-6. The Contracting Helix.

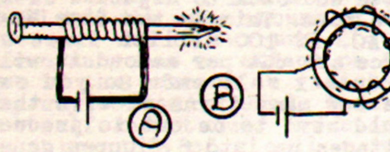
8-6. Experiment. A contracting helix experiment will serve to show how the magnetism generated by individual turns in a coil tend to pull it together. A coil of wire is suspended and with an end floating on the surface of Mercury. It can also work by using a flat metal surface. Current is then applied and the wire will raise up enough to interrupt the current flow - which will show on the meter. When the contact is broken the current is off and coil drops back again.



8-7. Coil Fields Attract.

8-7. Experiment. Attraction of coils. Wind 2 coils with about 100 turns each. Suspend one by the lead taped to the center for balance. Be sure they are hung close together. Apply the current

and watch them swing so their fields rest in the best magnetic position.

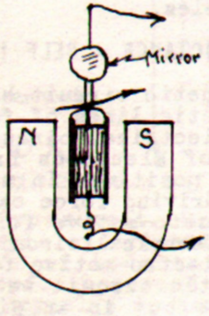


8-8. Attraction with Iron Cores.

8-8. Experiment. Wind a few turns of magnet wire around a nail and hook to a drycell. Use Iron filings to pick up. Note when current is off the filings drop off. Note difference in attraction with a few turns of fine wire and a few of large wire. You can try the coil without the nail and see the difference in attraction. The Iron core increases magnetism several hundred times. Test the compass needle for N and S poles.

A test with a Toroid, or a doughnut coil (B), wound without the Iron core gave 23 lines of force per square inch. With an Iron core it gave 40,000 lines, or 1739 times the magnetic effect with the Iron core.

Magnetism is used in so many different ways as transformers, coils, speakers, power supplies, chargers, magnetic brakes, dynamos, generators, magnets, and even in transmission of Sonar, Radar, TV, etc. Large electro-magnets are used in magnetic cranes to pick up scrap Iron.

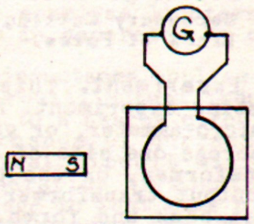


8-9. D'Arsonval Galvanometer.

D'Arsonval Galvanometer. Fig. 8-9. This is called the deadbeat galvanometer where the hand returns to zero when no current flows. It is called the D'Arsonval movement and is the principle of most DC Ammeters, Voltmeters, and even motors. It is very sensitive to the smallest voltage- and can be used in most experiments in this Handbook.

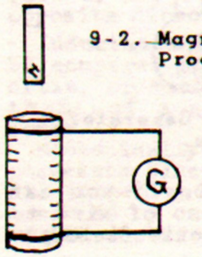
9. MOVEMENT IN A MAGNETIC FIELD PRODUCES ELECTRICITY.

In 1831, or 12 years after Oersted discovered that an Electric current in a wire produced magnetic lines of force, Faraday discovered that moving a coil thru a magnetic field produces a current of Electricity.



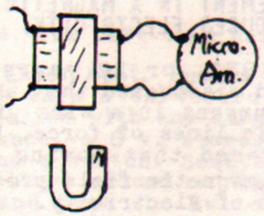
9-1. Faraday's Experiment.

9-1. Experiment. Here is Faraday's simple experiment that you can do. Just a single turn of wire hooked to a micro-ammeter or Galvanometer. Draw a magnet past it and watch meter, and see polarity of current. Now, draw the other pole past it. The faster it is moved - the greater the current produced. A very simple experiment - but in those days "who'd a thunk it?"



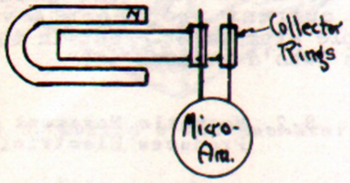
9-2. Magnetic Movement Produces Electricity.

9-2. Experiment. A little more practical experiment than Faraday's. Take a 2" Crystal set coil and hook an 0-500 micro-ammeter, or galvanometer across it. Push a bar magnet inside the coil and watch the reading jump. It will either act positively or negatively. Pull it out and the current reverses the reading. Our meter gave 20 micro-amps. or more on a test.



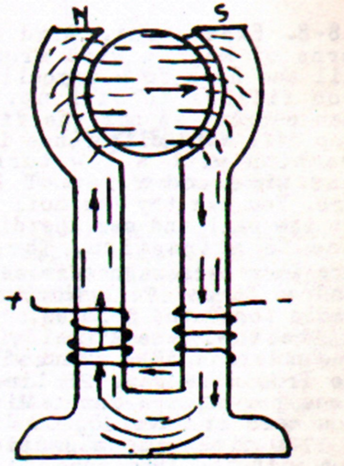
9-3. Secondary Cutting of Lines of Force.

9-3. Experiment. This is an interesting experiment. Hook an 0-500 micro-ammeter, or galvanometer across one side of an Audio transformer, or the primary of an output transformer. Swing a magnet back and forth, close to the ends of the transformer. You will get a reading of about 80-100 micro-amps. on the positive side. Swing it over to the other side of magnet and it goes negative. The idea here is that the magnetism is transferred to the core and then to the winding and to meter. The magnet doesn't produce Electricity directly, but it is the cutting of the lines of force that make it.



9-4. Electric Generator Principle.

9-4. Experiment. If you can rig up a turn or so of wire to turn inside a magnetic field you have the principle of the Electric generator. As it is swung around the current rises to positive and back to negative in a wave form. This is the **Sine Wave** of AC. If 100 million lines of force are cut per second it will produce 1 volt emf. So you can see how many turns of wire that would have to be cut to produce voltages up into 6 figures generated in a power house. It is



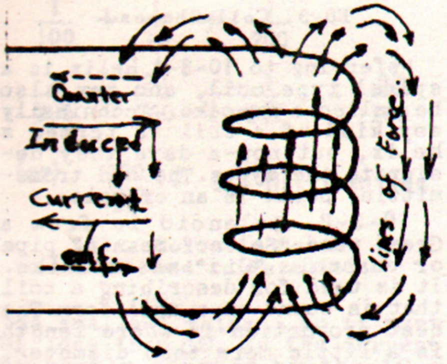
9-5. Generator with its own Electro-magnetic Field.

shown a little more extensively in Fig. 9-5. Here the core is soft Iron laminations and the magnetic field produced by the large number of turns on the field poles. Note that the windings are reversed to get the N and S poles.

10. INDUCTANCE - SELF INDUCTANCE

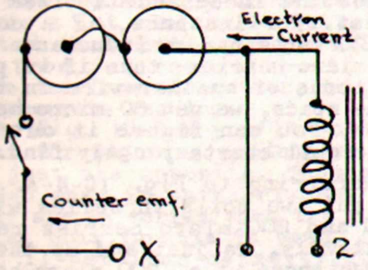
A magnetic circuit has a flow of magnetic lines of force, but in an Electrical circuit we get a flow of Electrons from negative to positive. In magnets we have a driving force called M.M.F. (Magneto-motive force). but in an Electrical circuit we have emf. (Electro-motive force). In a magnetic circuit we have Reluctance but in an Electrical circuit we have resistance.

Self-inductance is the same as Inductance. We have inductance in a coil if there is a current there or not. A 100 mhy. coil still has the same amount of inductance if no current flows. Inductance has no effect on DC, but if the current is varied in any way, or AC is used, then we get self-inductance. Inductance is a property of a coil - just like the appearance of it is a property.



10-1. Self Induced Coil.

We have seen how a wire with DC can generate lines of force around it. If we use AC, or vary this DC in any way, we generate a Counter emf (10-1) in the same coil circuit. This runs in an opposite direction to the original Electron current flow.



10-2. Counter emf.

10-2. Experiment. Here is a good, simple experiment to get the value of Inductance and counter emf. impressed on you. Rig up 2 drycells in series and run to a SPST Toggle switch and an Audio choke, or one side of an Audio transformer. Wet your fingers and touch (1) and (x) & have someone turn the switch on. You will feel no shock. Have him switch it off and you may possibly detect a little shock. However, touch (x) and (2) and have him do the same. When "on" you won't feel a shock, but note the strong shock when he cuts the switch off. You did not feel the DC- but when the inductance in series you got a good shock. This latter was the counter emf. generated by the coil, and going in reverse direction to the original Electron current flow.

An Electric bell will work the same if you bridge the contacts with your fingers. The same principle of breaking the circuit is used in some gas lighters where a spark is generated by counter emf.

Self-inductance applies to the same circuit. Mutual inductance applies to a nearby circuit.

Any change of current in an Electrical circuit will cause the generation of counter emf, or voltage in that same circuit, or a neighboring one. The property of a circuit which enables it to exercise this power is called Inductance. The greater this ability the greater the inductance. By forming conductors into coils the inductance is greatly increased, as the lines of force fall back on adjacent turns. A coil used on account of its inductance is called an Inductance, altho it would be more properly called an Inductor. Its counter emf. opposes any increase or decrease in voltage - so it offers resistance to the flow of AC, etc. as it flows in opposite direction to current.

Inductance in Engineering may be compared to a mechanical inertia, or mass; a resistance in terms of a quasi-frictional force.

Mechanically- a body in motion possesses Kinetic energy that is dissipated and the energy being measured by one/half the product of the square of the velocity.

Electrically - current flows until dissipated and measured by one/half the product of the self inductance and the square of the current. The Electrical analog of mechanical inertia is Inductance, as the current does not exactly contain Kinetic energy as does water, etc. Inductance is the resistance of a coil to AC, pulsating DC, or high frequency. Inductance is the coefficient of self-induction and is the product of the number of turns and the number of lines of force thru the circuit.

The Standard of Inductance is one square turn of wire.

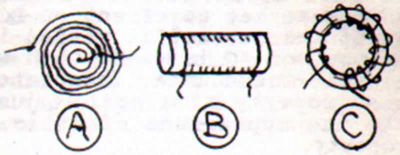
The Unit of Inductance is the Henry. A circuit has an Inductance of 1 hy. when a current, changing at the rate of 1 amp. per second, induces a counter emf. of 1 volt in the circuit. Or, if a current of 1 amp. in a circuit develops 100 million cutting lines of force - the inductance is 1 henry.

One hy. is a large unit - like a Farad is a large unit in capacity measurement. Henries are used in Audio chokes, transformers, etc. However, for coils we use the millihenry (mhy.) or one thousandth of a henry. For the smaller coils we use micro-henry (μhy.), or millionth of a henry.

The simplest coil is one turn of wire - or a straight bar as used in HI-F circuits. Both the wire and bar have Inductance, resistance, reactance to AC, etc., altho small. Adding turns just adds up the same properties of the single turn but in different proportions.

A long wire, we'll say 50 ft., has Inductance, resistance, etc. just like a 1-turn coil. But if it is wound around a form to make a coil of many turns, then the Inductance is increased many times. If an Iron core is inserted into the coil- the Inductance is again greatly increased. The self-inductance builds up between all the turns.

As we have seen, the field in one or more layered coils is parallel to the axis of the coil and proportional to the product of the current in amp. and the number of turns on the coil. This product is called the **Ampere turns** of the coil.



10-3. Coil Shapes.

Referring to 10-3-A Helix is a spiral type coil, and may also be called a Pancake. Technically any kind of a coil is termed a helix, but now-a-days they designate the types. The old transmitting helix is an example.

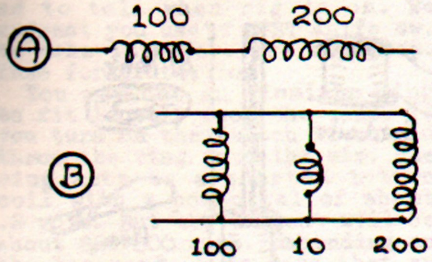
10-3-B. Solenoid is from a Greek word "Soleno" meaning pipe or channel. "Oid" means alike. It is used for describing a coil that is wound on a coil form. The best proportion is where length is a little more than diameter. Basket weave is also a solenoid.

10-3-C. The Toroid coil is bent into the form of a doughnut and used quite extensively now in filter circuits, etc. (See HB-6). It has a concentrated field where very little loss in lines of force are encountered.

Doubling the turns on a coil makes the Inductance **4** times as great. For instance, if a coil of 20 turns has an Inductance of 15 micro-henries- then if we put 40 turns of smaller wire in the same space, we get 60 micro-henries. You can figure it out on some coil charts you may find.

Referring to Fig. 10-4-A. if we put two coils in series with 100 and 200 micro-henries respectively, we just add up their Inductances, i.e., 300 micro-henries. This is the same as with resistors. Coils in series are usually called "loading coils."

Now let's look at Fig. 10-4-B and we find 3 coils in parallel. Their values are 100, 10 and 200 micro-henries. The rule is that the final figure is less than



$$\frac{1}{100} + \frac{1}{10} + \frac{1}{200} =$$

$$\frac{2}{200} + \frac{20}{200} + \frac{1}{200} = \frac{23}{200}$$

$$\text{(or)} \quad \frac{200}{23} = 8.7 \text{ Millihenries}$$

10-4. Coils in Series and in Parallel.

the smallest value - so it must be less than 10. As the current is mostly shorted by the 10 - smaller amounts of current leak off thru the 100 and 200. You can see how Electrical laws work together- and don't we know that a coil is a form of resistor? To make it easier - we just divide the numerator (23) into the denominator (200) and get 8.7 micro-henries for the circuit. This is not technically accurate but it is a lot easier. It is to be noted that coils in parallel must be far enough apart, or shielded from each other, to get an accurate reading.

Re Fig. 10-4-B you'll notice that for figuring condensers we do just the opposite. They are added when in parallel. But if they are in series then the parallel coil formula is used. So, you'll get less capacity than the smallest value in series.

Inductance of stranded wires is about the same as for solid wires of the same circular mils area.

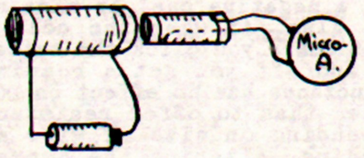
When considering self-inductance of power lines at 50-60 cy. the greater the diameter of the wire - the smaller the self-inductance. For Iron wire the self inductance is greater than for Copper- probably due to the magnetic effect. For (2) #10 light wires, spaced 30" apart for a mile - the self-inductance of each wire is only 2.13 mhy.

The self-inductance within a turn prevents AC attaining its maximum value. It also prevents it from reaching a minimum value at once. This is called Current lag, and due to the counter emf. generated in each turn. The AC resistance of a single layer is much less than for a multi-layer at Radio frequency. This is the reason you see coils at HF made single layer and spaced. For the lower Radio freq. as Broadcast & long waves - they may be honeycomb, or universal wound. (HB-6)

Air gaps lower the self-inductance of a coil. Air gaps are used in most transformers, audio chokes, etc. and are attained by covering laminations with Shellac or Varnish to loosen them up in stacking the cores.

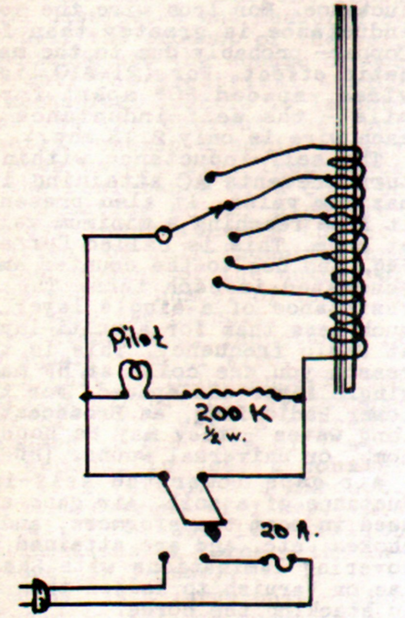
11. MUTUAL INDUCTANCE.

Mutual inductance is the ability of one circuit to produce an emf. in a nearby circuit, or circuits, when the current in it changes. It may be shut on or off, or reversed at high or low speeds as HF and LF, or it may be fluctuated or modulated DC.



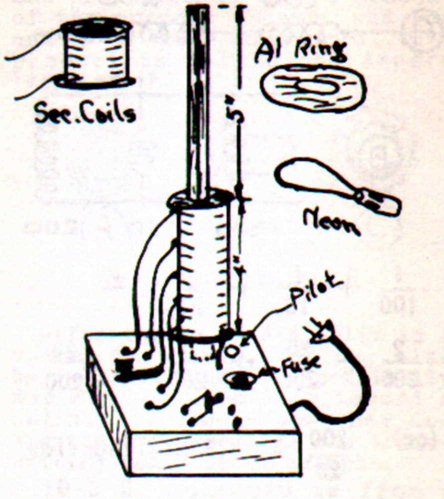
11-1. Movement is required for Mutual Inductance.

Experiment 11-1. You will not get mutual induction unless a change occurs in the lines of force. It is easy to prove this by rigging up a 100 turn 2" coil and hook to a drycell. Wind one 1½" in dia. to slide inside the 2" coil. Hook a micro-ammeter a-



cross the 1½" coil as shown. You push the coil inside and watch the meter. When the coil is still there is no transference of energy - but as soon as it is moved there will be a distinct sign on the meter. Possibly when you pushed it in you got a positive reading. If you pull it out you get a negative one, or vice versa. Also, if when the coil is stationary you click the battery on and off you get a reading. Inductance has no effect on DC - other than to offer resistance depending on size of wire and winding. Altering the current flow in the first coil causes the lines of force to increase, decrease or reverse, and it has been shown that any movement of the lines of force produce Electricity. In this case it is produced in the second coil.

The Primary, or the first coil is the exciting coil, or the Inducer. This induces current into the Secondary near it by mutual induction.



11-2. Repulsion Coil & Experimenters' Transformer.

11-3. Experiment. This is a good rig for the Experimenter to keep around the shop. It has a lot of uses, but the most important here is to show the power of an induced voltage.

Obtain a bunch of Iron, or stovepipe wire, and cut into 10" lengths. If not straight they can be rolled between 2 boards. Drop them in Shellac, or Varnish and let dry on some strips of wood. Bundle them up into a core about 1" in diameter - and wrap it solidly with plastic Electrician's tape. This Shellac insulates the wires from each other to keep down Eddy currents and consequent heating. The tape also helps insulate the core.

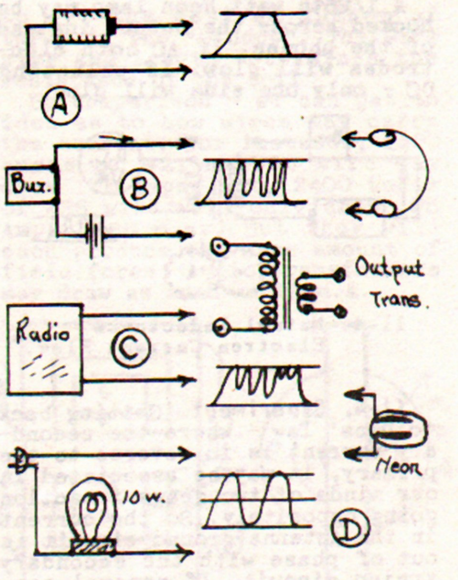
Wind about 200 ft. of #18 Enameled wire for the primary - preferably on a cardboard, or Bakelite tubing with wooden ends and make solid. Start winding 1" from one end - and cover a distance of 4". The 1" is to fit into the box top. Bring taps out at 250-300-400-500-600 turns by running thru Spaghetti and over to the switch points. Leave 5" of the core above with which to experiment. The Dial lamp is used to tell when rig is on. We suggest you use a DPST knife sw. to make it safer. Use a 20 amp. fuse for protection.

You may cut an Aluminum ring to fit loosely over the core. If you turn on the switch it should throw the ring into the air. The ring acts as a shorted 1-turn coil with a potential of about .3 volt. But the current will be about 300-600 amps. depending on the tap used. Lens says that an induced current flows in opposite direction in mutual induction circuits and causes the ring and coil to repel each other. This is done best on the 400 500-600 turn taps. The ring will soon become warm due to passage of hi-amperage current.

Various secondaries may be wound and slipped over the core for experimental use. It may also be used to light lights, for filament transformers, etc. Use the Turn Per Volt (tpv) ratio to figure secondary voltage. If you are using the 600 turn tap at 110 volts you have about 6 tpv. On the 250 tap it is 250/110 or about 2 tpv. It is not a good idea to use the 250 turn tap unless you have a secondary pulling on the core or it may blow a fuse. A one-turn coil may be hooked to a 1/25th watt Neon lamp to make it "light thru the air!"

A fine wire portable secondary coil, with many turns, may be used to step up the voltage. Using the tpv. rule again, if we wind a secondary with 1250 turns and put on the 250 tap - we'll get 5x110 or 550 volts on the secondary. Many interesting experiments can come from this.

11-3. Experiment. An interesting setup for listening to various types of current is shown. Use an output transformer, with secondary going to phones. (A) for DC - hook up a drycell. You will note the only time you hear anything is when current is put on or off. You won't hear pure DC. (B) Hook up a buzzer, or a bell to a battery and the primary. You will hear the "tone"



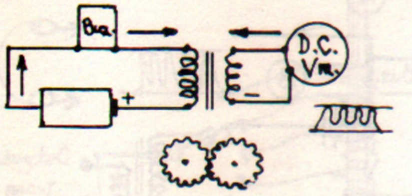
11-3. Kinds of Current.

in the phones. This is intermittent DC - as it is run off the battery and the contact is made and broken many times per second as compared to AC. By pushing the contacts together you raise the tone (frequency). This is the principle used in vibrators in Auto radios, to make the 6 or 12 volt battery go up thru the power transformer to be stepped up.

(C) This can be hooked to the output of any Radio or Crystal set - and you will get pulsating DC. The modulated signal comes into the rectifier (crystal or tube.) and only one side is used. So, it is really pulsating DC.

(D) Run 110 circuit thru a 10 watt lamp, for protection, and into the transformer. You will now get a 50-60 cycle hum, depending on your power line. This is pure AC. One may add a signal generator's output to the transformer and get RF (Hi-F) or audio (Lo-F) frequency tones. This bit of listening will help to identify types of current.

A 1/25th watt Neon lamp may be hooked across the output instead of the phones. If AC both electrodes will glow. If pulsating DC - only one side will glow.



11-4. Mutual Inductance
Electron Current Flow.

11-4. Experiment. Getting back to Lenz' law - where the secondary current is in reverse to the primary, it may be associated in our minds of two gears in action going oppositely. So the current in the Antenna-ground circuit is out of phase with the secondary tuning circuit. If several secondaries are wound close to the primary source of power - the current flows in opposite direction to the primary, in each of the circuits. If the secondaries are very far away from the primary, even very sensitive instruments cannot detect the current induced. For the experiment hook a drycell up to a buzzer & run into the primary of an Audio transformer. On the secondary hook a DC voltmeter with correct polarity. The arrows show the direction of the Electron current flow.

However, when you disconnect the battery you will notice the meter jumps below zero - showing that counter emf. is being generated, and to be opposite in phase, or direction. You will also notice this is very strong as the lines of force drop back onto the wire. This is one reason we find an Electric lamp burned out after we turned it off. Also, you will hear said: "well, the Radio played alright last night, but now it won't go on." This strong counter emf. burned out a tube, transformer, or blew a condenser when the set was turned off. The ordinary telephone receiver can detect clicks of .003 amps. of current, but it is the counter emf. generated that you hear.

Mutual induction between primary and secondary depends on several things. (1) The greater the number of turns of wire on the coils the greater the transference of energy to the secondary. (2) The size of the coils & wire regulates the coil field. (3) The distance between coils. The closer they are the more energy is transferred. (4) The position of the coils. Mutual induction is greater when the coils are placed parallel to one another- or one inside the other with planes running the same direction. If placed at right angles - practically no mutual induction occurs between them. (5) Nature of material that separates them.Air has little shielding effect between the coils.But if Iron is placed between them it tends to absorb some of the lines of force and keep them up closer to the coil. Brass and Copper will also confine lines of force.

We run into many different examples of mutual induction in daily life. Noisy power lines can cause trouble for several blocks away by induction. Power companies have "detection cars" that seek out the offenders - in many cases "bugs" or transformers on the poles.

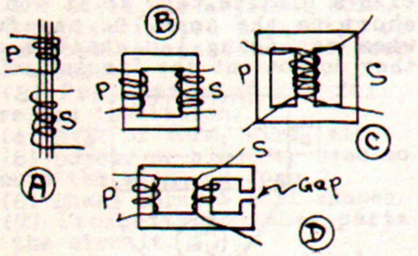
Cross talk from phone lines often results from wires being too close together. Crossing or twisting wires of the same circuit tends to lessen this evil. This also applies to 110 volt cords that are twisted so the lines of force tend to neutralize each other.

**A Varian magnetometer is to go into the air with a Satellite under present plans. It may help solve problems about Sunspots' relation to magnetic storms; why Cosmic rays are more active at the Poles and why Auroras affect Radios. Varian claims invention but Gauss (1835) had the first.

12. LOW FREQUENCY TRANSFORMERS.

As this is a broad subject we will only attack it in relation to coil coupling, etc. Low frequency transformers include Audio transformers and chokes, power transformers, AC line transformers of various types, etc.

What is looked for in low frequency transformers is unity, or perfect coupling.This is as near 1:1 as possible. It can never be attained in air-core coils as so many lines of force are lost in the air. As said before, with an Iron core the lines of force tend to concentrate on the core path - so very little magnetism is lost. The greater the lines of force hug the core - the more energy will be transferred to the secondary.

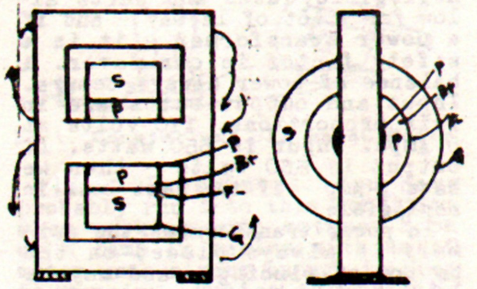


12-1. Transformer Core Shapes.

Most transformers in Radio use closed core transformers (12-1). (A) shows an open core - and is seldom used except in various spark coils, etc. (B) is a type used in large heavy duty transformers, etc. (C) is where the windings are both made on the center leg - and used in most Radio power, chokes and audio transformers. (D) shows one type with an air gap - to keep down losses from Hysteresis.

By winding transformers with a fine wire- and a very thin layer of insulating paper between - we are able to get a lot of turns into a small space. We are also able to cut down the heat loss that would be generated with a larger wire.Wire must be of sufficient size to carry the wattage - and still be small enough to get the desired number of turns in the "window". The wire size and length determines the resistance of the coil

By comparison - we can get an idea as to how wires may carry the current. For instance, 2400 turns of #21 magnet wire may draw 1.5 Amps. But, 2400 turns of #36 wire will only draw .06 Amps. (60 m.a.) But they will each produce the same amount of field force. Audio transformers may draw as much as 25 m.a.



12-2. An Audio Transformer.

Most present Audio transformers are wound like (12-2) with the primary on first - and the secondary over it. The lines of force are kept where they belong - near the core. It is also much easier to wind them - as various windings may be wound over each other without removing the form from the winder. The order of proper connections is shown, altho if you get an Audio that howls - just reverse one side. Sometimes the leads aren't marked correctly. A good quick way to check ratios of transformers is to check DC resistance of the primary and secondary. If they measure 1000 and 3000 ohms the ratio is close to 3:1. If you want 1:3- just reverse it. Don't do any switching with a power transformer unless you are sure of your windings. 3:1 is used in tube sets. But in Transistor operation they use the lower resistance on the secondary.

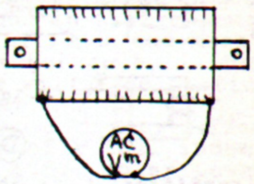
As Physics' students know "we cannot add or subtract energy -

"just change it around." So, in figuring input and output voltages of transformers - we won't get the exact ratio. There is some loss in heat due to Hysteresis and heating of wires. A transformer is considered 98% efficient if the input wattage is 1000 and the output is 980. This shows a 2% loss in heat - & is a good transformer that will do this. When re-winding transformers, etc. we do not have to worry about this loss - as it is negligible. Tubes and parts allow for a lot of leeway - and if a power transformer - it is a safety factor in our favor. A balance of power always occurs. Input and output watts are in fair proportions. 110 volts at 5 Amps. input is 550 watts. If output is 550 volts - then we have 1 Amp - if the heat loss in negligible.

In power transformers the primary is always placed on the bottom of winding - and may be larger wire than the secondary hi-voltage, as it must carry the wattage of the filament windings too. As filament windings are apt to be bulky - they are placed on the winding last. If the primary or secondary is burned out it doesn't pay to re-wind them, altho we used to do it when they were not obtainable or too expensive to buy.

So, our main overhaul job on a power transformer would probably be the filament windings. If you have a 2.5 v. winding you'd like to make into a 6.3 v. here is how you proceed. Hook up the power transformer and check the correct output voltages of the filament - we'll say it is 2.7. Now dismantle the core piece by piece. Start removing the filament winding and count each turn - and write the total down. You will observe that the 2.5 volt filaments are heavy wire - due to heavy current drawn by 2.5 v. tubes. Now, you can use smaller wire for the 6.3 v. and you will have to, in order to get the additional turns into the window of the core. They do not center-tap the 6.3 v. windings now as one side is grounded in the circuit when wiring up.

Taking the TPV ratio - we'll say 2.7 volts required 54 turns, then the TPV ratio of the whole transformer is 20. This goes for input and output. Say we want to wind 6.3 volts- we wind 6.3 x 20 or 126 turns of a smaller wire in the same space. Without unwinding the transformer we can now tell how many turns we have in the primary, i.e., 20 x 110 or 2200. Or on the secondary at 650 volts x 20 is 13,000 turns. As to size of new filament winding, you can check a current-carrying capacity chart for wire (page 16, HB-6). When replacing windings - be sure you wind them tight, as none of us seem to get them as compact as the factory. Also insulate well with Electrician's plastic tape so it won't short to the core. Be careful when replacing laminations so they do not cut the insulation.



12-3. Wagner Series Transformer.

An interesting type of power transformer is shown in Fig. 12-3. It is called the Wagner series transformer. It uses a Copper bar ½" x 3" x 12" long to form the primary. It is used in power houses to measure up to 60,000 volts - as this hi-voltage would burn up any meter connected directly. Around this straight bar are wound many fine turns of magnet wire. As we know, one straight wire throws off lines of force - so the induction is picked up by the secondary to the meter. The fine wire cuts it down so much that is has but 2 to 50 watts on the secondary. I worked around a power house at Big Creek, Calif., awhile in 1920, where they used these series transformers. These large busbars ran along on concrete foundations, and looked perfectly harmless. They had fences around them - and we were warned to stay out - which was heeded by everyone.

13. AC RESISTANCE.

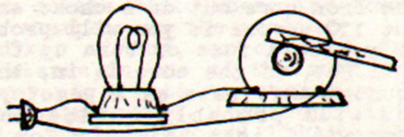
There are many things that may cause resistance to AC flow thru coils, or magnetic circuits. For general usage they are combined into the term AC Resistance. They vary in importance depending on the nature of the coil and its use. AC Resistance is higher than the Ohmic resistance. The following classifications include most of them.

(1) Counter emf, or regeneration of another current back onto the wires, or adjacent coil.
(2) Distributed capacity, or capacitative reactance between all wires.
(3) Properties of the form, wire and insulation.
(4) Size of form, wire, etc.
(5) Dopes, or binders, used to secure the wire and form.
(6) Sharp turns & coil shapes.
(7) Proximity to other parts in the circuit.
(8) Frequency of the signal.
(9) Shielding of the coils.
(10) Skin effect, or circuit resistance.
(11) Temperature & humidity.
(12) Eddy currents and current lag.

To make a good coil we must take all these things into consideration. By experiment we can find which set of conditions is best. Regardless of all "Q" meters, etc. we find that if two coils are wound differently for the same frequency, and are tuned to a DX station, we can very quickly see which one works the best. By taking note of each of the conditions above, we are in for improvement. While there is no perfect condition- all we can do is to work toward this end.

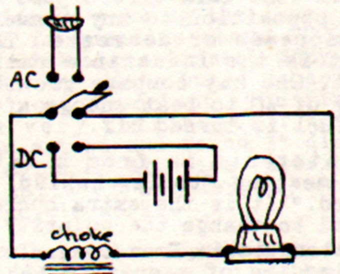
Plain DC resistance is a definite property, independent of frequency, etc. and depends on the size and length of the wire.

But, if a change occurs in the DC supply, then we start to get Inductive Reactance or resistance. Voltage lags thru an inductance, but it leads thru a condenser. Inductances will carry DC, but condensers will not. If an Inductor was required to carry DC, plus 2 AC frequencies, it would offer little resistance to DC. However, it would offer resistance to the AC frequencies -and a different amount to each.



13-1. Counter emf. in an AC Motor.

13-1. Experiment. You have probably run into this condition when working with motors. Hook up a lamp in series with an AC motor- one strong enough to keep it running. Notice the brightness of the lamp. Now, hold the pulley with your hand, or lay a board on it so the motor stops for an instant. See how the lamp lights up - showing there is no counter emf. generated by the motor coils. This emf. backfires into the AC line and offers resistance to the current, and it prevents lamp from lighting to full brilliancy. This is one of the best experiments to show the effect of counter emf.



13-2. AC-DC on a Choke Coil.

13-2. Experiment. In this we hook a lamp across a DC power supply - to read 110 volts when lamp is lit. Across the other side of the DPDT knife switch we hook the 110 AC line. When we throw the switch to DC we will find the lamp lights brighter than for AC. This shows the AC reactance in the coil in the form of counter emf. as in the motor. Using this in practice, - if we put an Iron core choke in series with the AC line when experimenting, we have less chance of blowing a fuse. If you take the Iron core out of a choke and put 110 across it you will probably blow a fuse or burn up the coil.But, if the core is in, the counter emf. acts as a Reactor. You will probably notice the lamp will light brightly for a second - showing it takes time to build up the counter emf. On DC it lights to full brilliancy and stays there. The counter emf is 90 degrees back of current.

You'll also notice that when an Electric locomotive goes on the level, or up grade, it uses Electricity. When it goes down it uses counter emf. as a brake.

Current decay is often used to describe current that decreases due to counter emf. Growth, then describes the slowness in returning to normal. Each of these may amount to .01 to .001 second - depending on the size of the Inductance and the core. The greater the henries of inductance, the slower it acts. However, once a level is reached in growth- the coil offers just the same opposition to any tendency to increase or decrease. This point is the Inductance rating point. One may compare growth & decay of AC to heat energy after the fuel is turned off.

Hysteresis is from a Latin word meaning "to lag behind; to retard." It is the extra current needed to change the polarity of the atoms in an Iron core. It is the lagging of magnetism behind the voltage that produced it. A good example is pulling Iron filings with a magnet - whereby it takes time to pull the filings over. When AC changes they are pulled the other way.

Hysteresis loss depends on (1) frequency, (2) density of the flux lines and (3) hardness of the core. As this loss is considerable in Iron core transformers the proper metal must be selected to keep heat losses down. Heating limits the permissible load of the transformer. Hysteresis depends a lot on the residual magnetism in a core.

Softest Iron is used in Electrical machinery so it will magnetize and de-magnetize quicker. If hard steel it would be necessary to have a very powerful field to magnetize and de-magnetize, or reverse the atoms.

It takes 10-12 times as long to magnetize a solid Iron core as it does a laminated one. The solid also de-magnetizes slower. Laminations produce air gaps between layers - as they are shellacked so each has its own lines of force. The air gaps also lessen Eddy currents, with less heat. One may use varnished Iron wires for a core - that works the same as laminations.

With wrought Iron (or ordinary sheet Iron) taken as 1.0, the best Silicon steel rates 0.25. Cast Iron is 4.0. So you can see Silicon steel (4%) makes the best transformer cores.Permalloy has a low Hysteresis' loss but a low intensity of magnetization.

Eddy currents run at right angles to the magnetic flux. They cause some loss in coils. A good example of this is the damping effect of a brass tube pushed in between pri. and sec. of a medical, or shocking coil, when the output is cut down.

Air core RF transformers are used in most sets because Iron would cause Hysteresis and Eddy current losses.But powdered Iron is alright. These losses greatly increase as frequency increases. Iron cores may be used up to about 15 kc. but at Audio frequencies they are OK. Hi-F currents produce more Eddy currents in adjacent wires. A serious loss occurs at frequencies above 3000 kc. Use wire as small as possible without increasing resistance, or by using tubing in-

stead of wire. There is a better size for each band and use.

Distributed capacity. Turns in a coil act as individual condenser plates - so that an inductance is not pure - but shunted by tiny condensers.This distributed capacity increases the inductance value - but skin effect of the wire tends to neutralize some of this gain.

At low frequencies this capacity is very small but it is fairly critical at high frequencies so must be taken into consideration in design. Some good examples are Honeycomb coils:

Number of Turns.	Millihenries of Inductance	Dist. Cap. Mmfd.
25	.039	30
100	1.3	24
1000	61.	13

See how much more distributed capacity we get, in proportion, when we use 25 turns than 1000.

There are several conditions where distributed capacity varies. (1) The longer the coil and smaller the diameter - the less distributed capacity.This is because the ends are farther apart - and there is a greater difference in potential at the ends. A long thin coil has less inductance than a "fat" one - for the same length of wire. Therefore, the greater the diameter the more the distributed capacity due to greater difference for a turn of wire.

(2) Distributed capacity also depends on the insulation around the wire. Air gives the best, so spaced windings are preferred for 20-40 and higher bands. Cotton insulation is next to air & considered good. Enameled is the worst as wire is closer together -just like turning in the plates of a variable condenser. Single layered coils have less distributed capacity than multi-layer. There is less dist. cap. with small wire than large, as the HF travels on the surface, but DC is all thru the wire. This is called the Skin effect.

(3) The kind of material and shape of the form have a lot to do with distributed capacity. The lower the dielectric constant the lower the dist. cap. Air or Celluloid seem to be the best, and with certain "mud" types having very high loss.

As we know, sharper tuning is facilitated by small capacity & higher inductance - what they usually term in Radio "Lo-C and Hi-L." You will note this when tuning at 1500 kc. against 600 kc. on the Radio,where the former sharpens up the stations.

Skin effect, or circuit resistance is one of the most important points to consider in designing coils. Apparently it's at a minimum around 1000 to 850 kc. It increases above and below this point, and very bad on HF, but it can't be helped beyond a certain point. When balancing Radios on BC, we used to "unknowingly" adjust our DX on stations at 1000 kc. which seemed to give best results.

As most HF travels on the surface, much of the wire is going to waste. This resistance to HF is why small, fine wire coils tune sharper than ones of larger diameter and wire. The untuned stations become greatly weakened under these conditions. In making coils of 1" or ½" in dia. for BC bands - very fine wire must be used and a lot of distributed capacity results. However, the stations tune sharper, and they have plenty of amplification to take up the loss.

On frequencies above 3000 kc. the dielectric losses, Eddy currents and distributed capacities are most important. The first 2 are very detrimental. Grimes made a test and found 1" diameter coils of #14 wire superior to ½" coils of any length, for 15 megacycle work.

We hope this Handbook has been helpful in clearing up some of the most important principles of Radio. Lack of space prevents us from going further into this interesting and intriguing field. Certain material will be covered in other MRL Handbooks.

another MRL Handbook...

$5\frac{1}{2}$ x $8\frac{1}{2}$
24 pages
3 charts
46 drawings

HB-6. "HOW TO MAKE COILS."

CONTENTS.

A FEW OF THE QUESTIONS ANSWERED IN HANDBOOK 6. Pages given.

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How is a jumble winding made? Where are they found? p. 4.
Give RF choke dimensions. p. 4
Several ways to wind single-layer coils. Bench winder. p. 5.
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How to make Xmtg. coils. p. 7.
Advantage of bank coils. What is an easy way to make them? 8.
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Advantage of Bifilar coils? To use in Crystal set. p. 19.
Details on making many types of plug-in and switch coils. 19.
Complete winding chart for our plug-in coils. p. 22.
Why is a slider used? Best way to mount one on a coil. p. 22.
Advantages of link coupling in receivers, transmitters and oscillators. How to make. p. 23.

This is a companion Handbook to your #7, as Magnetism and Coils tie in so well together. One could profit more by reading HB-6 after you have finished HB-7, as the latter is more elementary than coil winding.
HB-6 is slanted for the Novice or Experimenter, altho a lot of methods may be used to build up commercial coils if you wish. It represents a good many years - over which period we learned to "wind our own," and have selected the method best suited for each type of coil.
You'll find plenty to do in HB-6, and it will be most interesting. Same price and source as this Handbook.

S.S., St. Helena, Cal.: "HB-6 gives best and most thoro coverage on coils for Experimenters I ever saw in one book."
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