

DISSECTIBLE TRANSFORMER - large

Cat: EM1660-001 220/240V.AC. 50/60Hz.

DESCRIPTION:

The IEC **Dissectible Transformer** is a very useful instrument for the teaching of transformer theory and many other AC phenomena. It is designed to be strong and have a long life. The standard kit contains:

- 1x 'U' and 'I' laminated core, 35x35mm section, with feet for stability.
- 1x Strong clamp with integral carry handle.
- 1x Primary coil, mains voltage, with on/off switch and removable mains cable.
- 1x Secondary coil, low voltage with tapings for adding and subtracting voltages.
- 1x Spot welding coil with handles.
- Quantity of metal strips for spot welding.
- 1x Melting ring to demonstrate Induction Heating.
- 1x Heavy aluminium ring to demonstrate Thompson's effect.

EM1660-001 dissectible transformer kit



Physical size: 270x75x220mm LxWxH (over clamp) Kit weight: 6.15 kg

Laminated iron core section: 35x35mm Length: 135mm Height: 160mm (U + I)

The instrument is supplied inside a sponge foam lined carton for protection.



IMPORTANT NOTE TO INSTRUCTOR:

Some of the following experiments require either connection to the 240V.AC. mains or can create high voltages that can, if touched, hurt or perhaps injure students.

MANY EXPERIMENTS ARE VERY SAFE BUT PLEASE BE SURE TO KEEP STRICT SUPERVISION WHEN THE HIGH VOLTAGE EXPERIMENTS ARE IN PROGRESS.

KIT CONTENT DETAILS:

- 240 Volt primary coil, on bobbin, 800 turns, on/off switch, indicator lamp, 3 Core flex and plug. ***READ and FOLLOW THE INSTRUCTIONS FIXED TO THIS COIL. NEVER APPLY 240V.AC. UNLESS THE PRIMARY COIL IS FITTED TO THE COMPLETE AND CLOSED IRON CORE.***

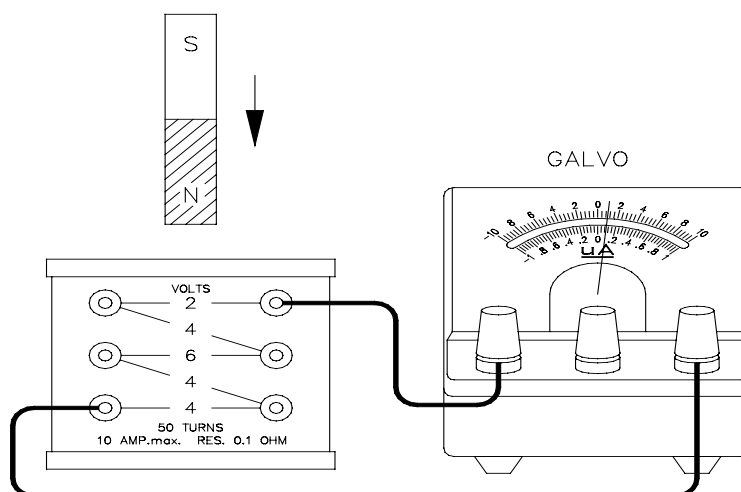
- Secondary coil with 70 turns of heavy wire for low voltage and high currents. This coil provides 20 Volts and is tapped at 2, 4, 12 and 16 volts with each tapping terminated to insulated 4mm socket head terminals.
- Laminated iron 'U' core. 35x35mm section
- Laminated iron 'I' core.
- Clamp for holding 'I' core to 'U' core with carry handle.
- Spot welder. Heavy current coil, with handles and welding points fitted. Including small samples of thin stainless steel for spot welding together.
- Induction heater for melting solder. (Short circuited secondary coil with handle)
- Thompson's Ring (Aluminium ring that hovers in the magnetic field).
- Booklet of experiments and instructions.

THE FUNDAMENTAL LAWS OF ELECTRICAL INDUCTION:

MAXWELL'S LAW: The EMF (voltage) induced in a coil depends on the number of turns in the coil and the rate of change of magnetic flux threading through the coil.

So, $EMF = \text{Change in magnetic flux} / \text{Time taken to change}$

LENZ'S LAW: The induced EMF is such that the current it produces causes the production of a magnetic field opposing the change in the original magnetic field.

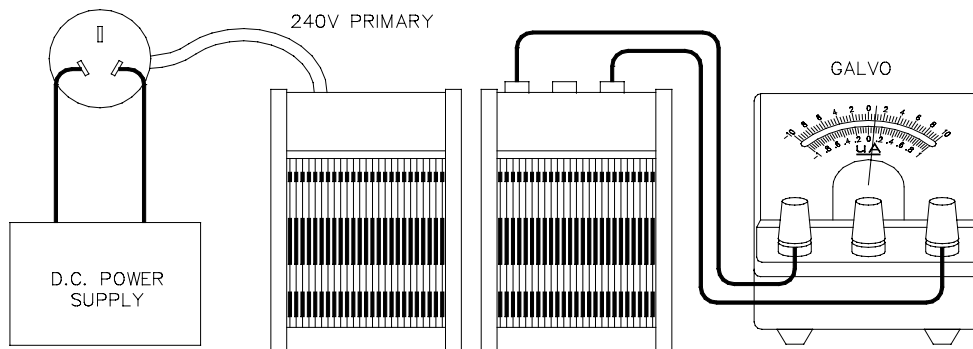
ELECTRICAL INDUCTION #1 'DC': Using a bar magnet:


- Connect the terminals for the largest number of turns of the secondary coil to a sensitive centre-zero Galvanometer to detect small currents.
- Insert a small Bar-Magnet into the bobbin and observe the meter.

NOTE: The meter indicates the presence of a current. A current does not flow unless there is an EMF. If the meter indicated a current flow, then the insertion of the magnet into the bobbin must have produced an EMF in the coil. Whilst the magnet is at rest inside the bobbin, no current is produced.

- Withdraw the magnet from the bobbin. Observe that current is again produced and that, this time, the current is opposite in direction to the first current.
- Change the end of the magnet you are inserting into the bobbin. What do you notice about the direction of the currents produced on insertion and withdrawal ?
- Alter the rate at which the magnet is inserted, from moving it in slowly to plunging it in quickly. What effect has this on the amount of current produced ?
- Instead of using the maximum number of turns on the bobbin, use progressively smaller numbers of turns. What effect has this on the amount of current produced ?

NOTE: In conditions like this, the current produced is a measure of the magnitude of the EMF induced in the coil.

ELECTRICAL INDUCTION #2 'DC': Using a solenoid electromagnet:


- Using the primary coil, connect the two active pins of the three-pin 240V.AC. plug to a low voltage DC power pack (say 20V.DC) such that the low voltage DC is applied to the coil.
- Place the primary and the secondary coils end to end on the table so that the centre holes are in line. Do not insert the iron core.
- Connect two terminals of any of the low voltages of the secondary coil to a sensitive centre-zero galvanometer.
- Turn on the power pack that will supply the DC current to the primary coil, then turn it off.

NOTE: That when primary coil current flows, a voltage is generated in the secondary coil which causes a current to flow through the galvanometer. This is because the current in the primary coil produces a magnetic field in the air which enters the bobbin of the secondary coil and induces a voltage in the turns. This is in a similar manner to the bar-magnet changing the magnetic field inside the secondary coil as described above.

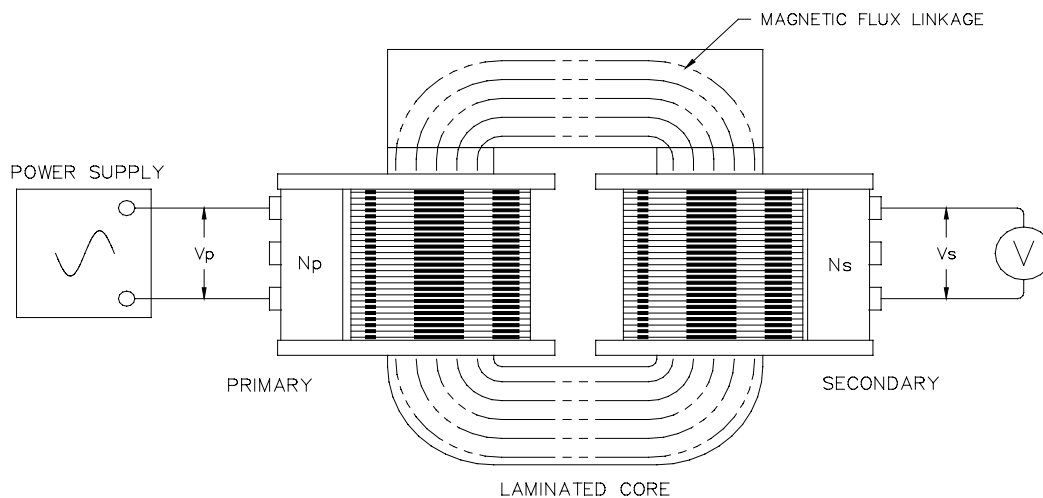
- Turn the primary DC current on again and note the secondary current.
- Leave primary current on: Is there any secondary current ? Explain.
- Turn primary current off: Is there any secondary current ? Explain.
- Move the ends of the bobbins closer together then further apart. Does this have any effect on the amount of current produced in the secondary ?
- Note the direction of current at the moment that the primary coil is turned on and note the direction of current when primary coil is turned off.
- Insert the 'I' core through both bobbins, or make an iron 'core' by using a number of steel retort-stand rods and pass them through both bobbins. Repeat the above on/off switching of primary DC current.
- What effect does the iron core have on the current in the secondary ? Explain.
- Turn the primary DC current on and off rapidly but regularly. What type of current is produced in the secondary ?

ELECTRICAL INDUCTION #3. LOW VOLTAGE 'AC': Using a solenoid electromagnet:

- Connect the primary 240V.AC. cable plug active pins to an AC power-pack at about 20V.AC.
- To the secondary coil terminals, connect an AC voltmeter or a multimeter set for AC millivolts operation.
- Turn on the low voltage AC primary supply and note the small AC voltage induced in secondary coil.
- Alter the input primary voltage and note effect on secondary volts.
- Alter the number of secondary turns used and note effect on the secondary volts.

NOTE: You may remove the iron core from the bobbins when operating the primary coil on low voltages because the current is low and the coil will not overheat.

CAUTION: NEVER REMOVE IRON CORE WHEN 240V.AC. IS APPLIED TO THE PRIMARY COIL.



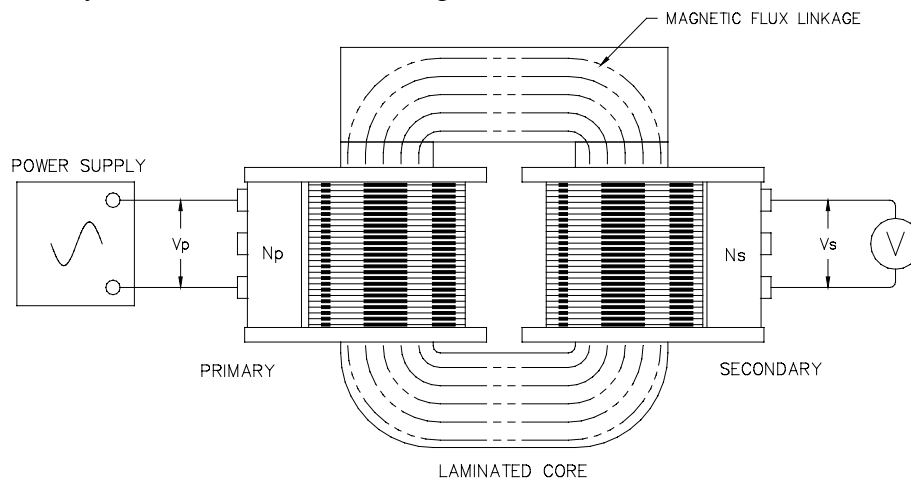
ELECTRICAL INDUCTION #4. HIGH VOLTAGE. 'AC': Transformer Operation:
Converting 240V.AC. to lower AC voltages.

- Mount the primary and secondary coils on the iron 'U' core. At this time do not fit the 'I' core or clamp.
- Plug the primary into a 220/240V.AC, 50/60 Hz mains power outlet.
- Place a hand firmly over both coils to stop one of them rising off the 'U' core and turn on the 240V.AC. primary coil for a short time. Which coil tried to rise ?
- Hold a hack-saw blade or razor blade lightly near the 'U' core and feel it 'chatter' with the alternating magnetic field produced by the alternating current in the primary coil.

NOTE: Although it is an alternating magnetic field, the effect on the blade is not changing from attraction to repulsion. For the first hundredth of a second the blade is attracted by say a north pole and the physical pull is reduced to zero for an instant as the polarity of the field reverses and then the blade is re-attracted by a south pole.

So, the 'chatter' is the result of a series of pulses of magnetic attraction with slight pauses between them.

- Apply an AC voltmeter (or a multimeter set to AC VOLTS) to the outlets of the secondary coil and record the readings from the various combinations of terminals.



WHILE THE IRON CORE CIRCUIT IS NOT CLOSED, THE CURRENT FLOWING IN THE PRIMARY COIL IS VERY HIGH. SO, UNDER THESE CONDITIONS, DO NOT LEAVE POWER TURNED ON FOR MORE THAN ABOUT 15 SECONDS OR OVERHEATING AND DAMAGE TO THE PRIMARY COIL WILL OCCUR.

- Notice that the readings do not agree with the voltages marked on the bobbin. Explain why.
- Now turn off the power, clamp the 'I' core firmly to the 'U' core and re-apply the power. Note that the magnetic noise or 'chatter' is reduced as the air-gap between 'I' and 'U' cores is reduced.



WHEN THE 'I' CORE CLOSSES THE IRON CIRCUIT, THE CURRENT IN THE PRIMARY COIL REDUCES TO A NORMAL VALUE AND THE POWER CAN REMAIN APPLIED TO THE PRIMARY COIL FOR PROLONGED PERIODS.

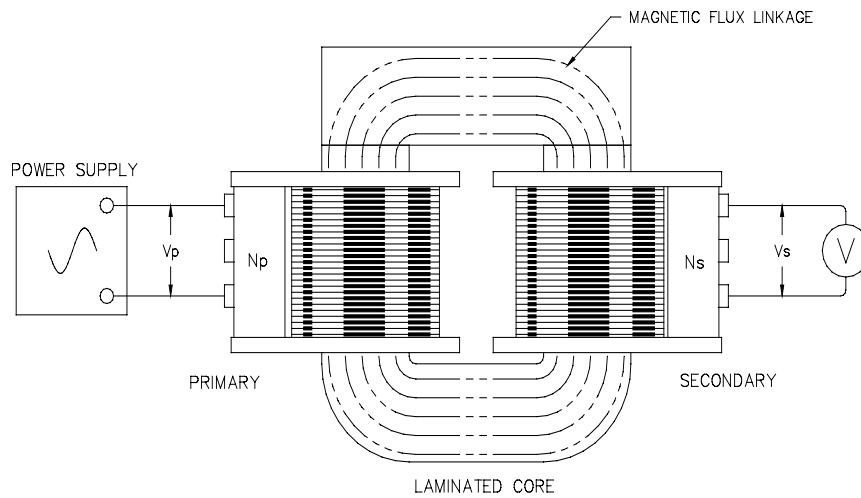
- Again read the output voltages on the secondary coil. They should now more-closely approximate the values as marked near the terminals.
- If you want to investigate the effect of 'Air-Gap' on the induced voltages, remove power, release the clamp, raise the 'I' core and insert paper or card of various measured thicknesses between the 'I' and 'U' cores and record the effects on the output voltages after clamping down the 'I' core on top of the paper spacer.
- If a continuous roll of paper was fed between rollers which opened and closed the air-gap of a transformer, as the paper varied in thickness, could the output voltmeter be calibrated to indicate the paper's thickness ?
- Sometimes you might notice that the 'I' core may often be difficult to remove from the 'U' core. If the current is turned off at the instant of its maximum value (peak of the sine wave), then the iron core would be fully magnetized and the 'I' core will be held firmly to the 'U' core. If this occurs, turn the power on and off again until you, by chance, turn it off around the moment that the magnetic field is zero. Then the 'U' core will not be highly magnetized and the 'I' core will slide more easily from the 'U' core.

'STEP-DOWN' TRANSFORMER: this is a common transformer function:

It was earlier described to connect the primary coil to 240V.AC. with the iron core fitted and the secondary voltages will approximate the markings on the secondary coil terminals. So far, you could have transformed 240V.AC. to 2V, 4V, 6V, 12V, 14V, 16V, 18V, and 20V.AC. depending on which terminals you connected and used on the secondary coil.

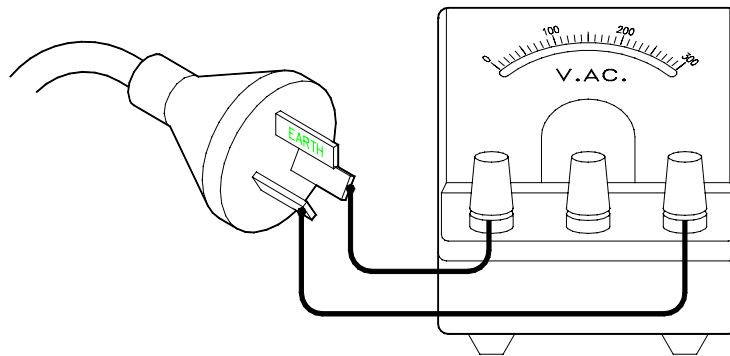
The voltage transformed from the primary to the secondary coils depends on the ratio of turns between the primary and the secondary coils. In transformer operation a rough guide is:

Number of primary turns / Primary coil applied (input) voltage = Number of secondary turns / Secondary coil (output) voltage.



PRIMARY		SECONDARY		RATIOS	
V_p	N_p	V_s	N_s	V_s/V_p	N_s/N_p

USE AS A 'STEP-UP' TRANSFORMER: this is also a common transformer function:



- Connect a high voltage AC voltmeter (up to 240V.AC.) to the active terminals of the three-pin plug (the pins that normally plug into the 240V.AC. mains power socket).

IMPORTANT NOTE: This voltage is very dangerous if touched. Take great care with the voltmeter connections to the plug. DO NOT TOUCH!

- Place the two bobbins on the 'U' core and clamp the 'I' core as for normal step-down transformer operation.
- Connect a variable voltage, low-voltage AC power pack to the MAXIMUM voltage terminals on the secondary coil (first and last 4mm socket head terminal). The number of turns between these terminals is 70 (or as marked on the coil). Since power is being **applied** to this secondary coil, we will now call this coil the 'new primary' coil and the other coil, which has 800 turns (or as marked on the coil), will be now called the 'new secondary' coil.
- From the power-pack, apply AC voltage to the new primary coil, gradually increasing the voltage from say 1V.AC. up to a maximum of say 20V.AC. whilst noting the high voltages produced and measured at the new secondary coil.
- If 20V.AC. is applied to the new primary at maximum number of turns, then you should get approximately 240V.AC. from the new secondary winding.

IMPORTANT NOTE::: BEWARE::: Such voltages are dangerous and can kill !! Keep strict supervision. Apply only low voltages to the new primary coil. Be sure that the voltmeter connected to the plug of the new secondary coil is able to safely measure such high AC voltages. Be careful not to touch the output connections.

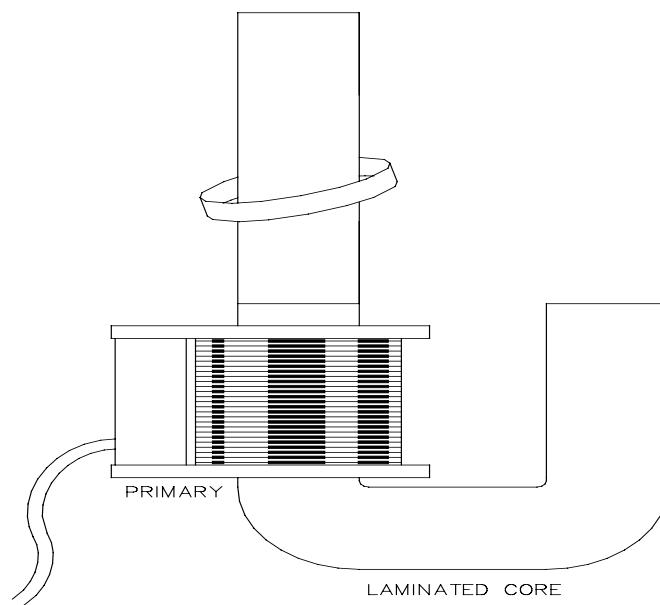
- Using the transformation ratio rule mentioned previously, what output voltage would you expect from this 'step-up' transformer if you applied 20V.AC. to the smallest number of turns (2V) on the new primary coil ?

THIS IS VERY DANGEROUS !!! DO NOT EVER ATTEMPT TO DO THIS ---

THOMPSON'S RING EXPERIMENT:

CAUTION: When the iron circuit is not closed, heavy current flows such that the primary coil can overheat very quickly and can be damaged. Experiments must be of short duration and always keep check on primary coil heating.

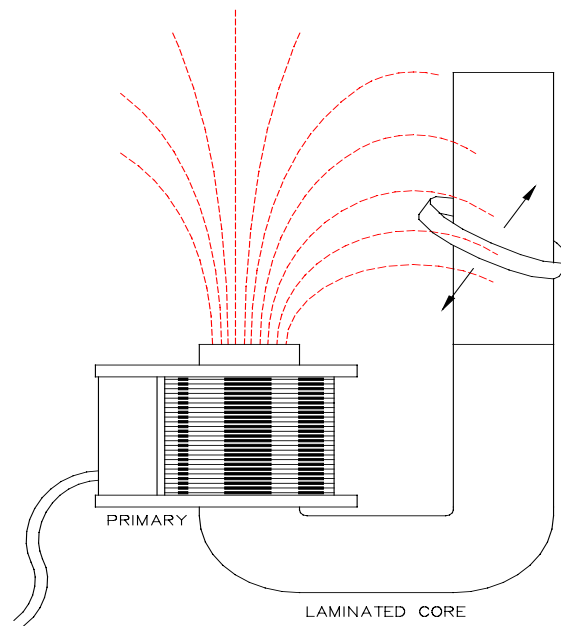
- Stand the 'I' core vertically as an extension to one leg of the 'U' core on which the 240V.AC. primary coil is placed.
- Place the aluminium ring over the iron 'I' core so that it rests on the upper face of the primary winding coil.
- Plug the primary coil into 240V.AC. mains.
- Stand back !
- Turn on the 240V.AC. power only for a moment. Explain why the ring throws itself from the core ?



EXPLANATION: When the first surge of current passes through the primary coil it produces a magnetic flux which immediately magnetises the big iron core, around which lies the aluminium ring.

This is a similar effect to thrusting a very strong bar magnet into the aluminium ring. It induces an EMF in the ring which produces a very heavy current in the ring. The direction of current flow in the ring is such that this current in the ring produces itself a magnetic field opposing the inducing magnetic field. The violent repulsion of these two magnetic fields hurls the ring up and off the core.

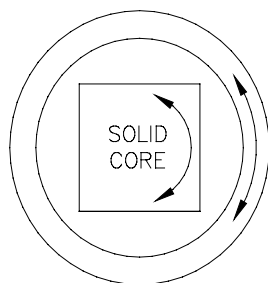
- Turn off the mains power.
- Place the 'I' core on the other leg of the 'U' core.
- Place the Thompson's Ring over it.
- Turn on the 240V.AC. again for a short time.
- This time it will again be raised but if you prevent it flying right off it will hang **suspended at an angle.** **WHY AT AN ANGLE ?**



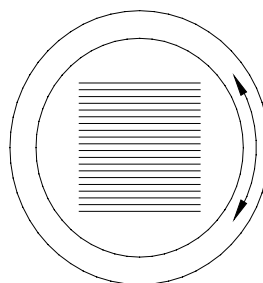
EXPLANATION: The explanation is that the magnetic field this time is not straight through the ring but tends to form a magnetic-leakage path across the gap between the long and short arms of the 'U' core. The field created in the Thompson's Ring aligns relative to this angle.

- Allow the Thompson's Ring to hang suspended in space for a few seconds only, then carefully feel it with a fingertip. If it is not too hot, remove it and feel the warmth that has been generated in it due to the very heavy current that has been flowing through it. The aluminium ring being large in cross section offers very little electrical resistance and, although the voltage is very low being a secondary coil with only one single turn (the ring), the current can be very high (perhaps several hundred amps).
- If the ring heats, why are the iron cores cold ?

They are cold because they are made of laminations (thin sheets of iron) and not solid metal so there is not a continuous contact of solid metal through which current can flow. If the iron were solid (not laminated), current would flow through it and heat would be generated in the same way as in the aluminium ring.



Solid core:
current would circulate and create heat



laminated core:
current cannot circulate



MAGNETIC INDUCTION EFFECT: INDUCTION HEATING

A closed circuit copper loop is provided with a handle attached. The primary coil is placed on one leg of the iron 'U' core and this loop is placed over the other leg instead of the secondary coil. Close the iron circuit and clamp the 'I' core in place.

When 240V.AC. is applied to the primary coil, a very high current is induced in the closed copper loop which behaves as a secondary coil which is short circuited to itself. It has a very low resistance similar to the 'Thompson's Ring'. A great deal of heat is generated in this short circuited secondary coil so that if pieces of wax or even normal solder are placed in the small channel of the 'Melting Ring' it will be seen to melt quickly. This form of heating is called 'Induction Heating' because the current causing the heating is INDUCED into the coil by transformer action.

Make a joined loop of thin solder wire the same size as the Melting Ring by twisting the ends together and lay the solder loop in the small trough of the Melting Ring. Since this solder itself now is a short circuited turn, heavy currents will flow directly through this solder loop and the heat generated will melt it very quickly without heating the Melting Ring very much.

SPOT WELDING

The Spot Welder consists of about five turns of heavy gauge insulated copper conductor which behaves as a secondary coil. It is fitted with a pair of contacts and insulating handles. When the handles are squeezed together, the two contact points are brought together to clamp the pieces of metal being spot welded. These contact points should be kept very clean because any oxidation present will cause a resistance to the heavy flow of current that is required for spot welding.

Two strips of thin material to be welded (thin stainless steel) are held between the contact points as the handles are squeezed gently together for a few seconds. The resulting heavy current generates very localised heat in the strips to be welded, until they become red hot and the metal softens. At this stage, slightly heavier pressure on the handles presses the two metal strips to be welded into each other and, upon the release of the pressure and cooling, a 'spot' weld occurs.

Light gauge stainless steel or high-carbon steel is the most suitable material for spot welding because it has a high electrical resistance and greater heat is produced for a given current.

Reducing the pressure on the points during welding will often increase the resistance a little to cause a larger 'hotspot' and better welding. A second weld is not usually as good as the first weld since there is a conductive path already established by the first spot weld and current through the second 'spot' is thus reduced.



INDUCTIVE REACTANCE

A length of wire has a certain resistance to the passage of electrical current depending on:

- The length of the wire.
- The cross sectional area of the wire.
- The material of which the wire is made.
- The temperature of the wire.

If a length of copper wire is wound on a bobbin into a coil and an iron core is placed into the bobbin and alternating current (AC) is passed through the coil, a phenomenon known as 'Inductive Reactance' occurs. The coil and core assembly is called an 'Inductor' or sometimes a 'Choke'. It offers a special kind of 'resistance' to the passage of AC current. This special type of 'resistance' is known as IMPEDANCE when it is combined with the usual resistance factors.

To illustrate this, perform the following experiments:

- (A) Take the 240V.AC. primary coil and connect leads to the two active connections of its three-pin plug. Connect to the smooth DC output terminals of a variable output power pack. Record the DC current for DC voltages ranging from zero to 7V.DC.
- (B) Insert the 'I' core in the coil and repeat the above observations.
- (C) Mount the coil on the 'U' core, close the iron core by clamping the 'I' core into position. Repeat the above observations.
- (D) Now use an AC voltmeter and an AC ammeter and repeat experiment (A) above, but this time use zero to 20V.AC. power.
- (E) Repeat experiment (B) above, but this time use zero to 20V.AC. power.
- (F) Repeat experiment (C) above, but this time use zero to 20V.AC. power.
- (G) Apply say 15V.AC. to the coil without an iron core, then insert and remove the 'I' core from the coil. Note the effect on the AC current through the coil.

The above experiment will show the inductive reactance of a coil fitted with an iron core when used with AC at mains frequency (normally 50 Hz).

EXPLANATION: The explanation is that when the current alternates and the magnetic field through the coil changes, an EMF is produced (induced) simultaneously in the coil which is opposed to the applied EMF at any instant, so the effective EMF applied to the coil at any instant is reduced and hence the current through the coil is also reduced. This induced reverse EMF is often called the 'Back EMF'.

For all calculations, use the following data for the 240 V.AC. primary coil.

240 V.AC. PRIMARY COIL: Close to 3.3 turns/volt.

Turns: 800. Max.operating current: 2.0 amp. Approx.Resistance: 6.6 ohms

With 'U' core only (not 'I' core) primary coil current is approx 4 amps.

Designed and manufactured in Australia