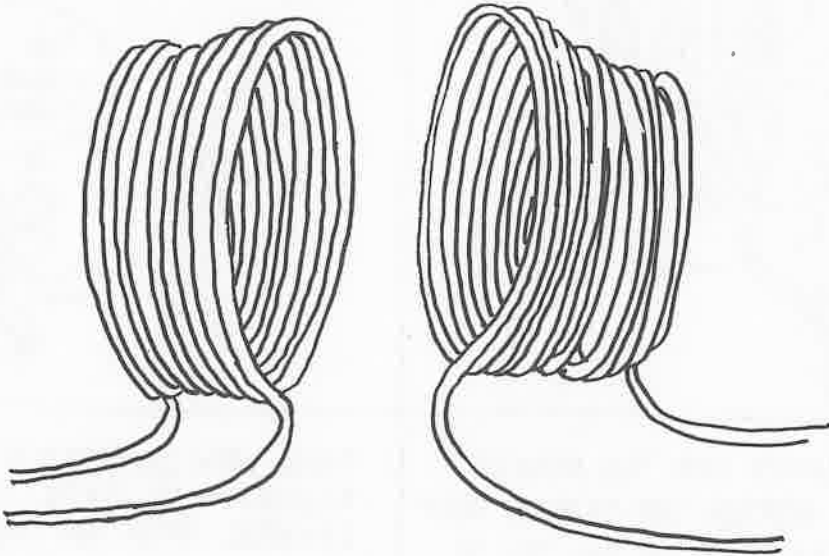
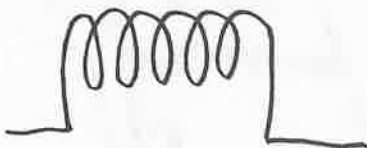


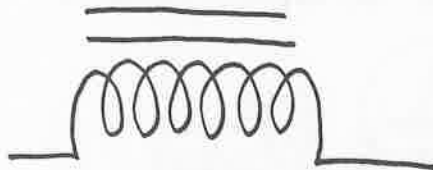
◊ CHAPTER 21 ◊ INDUCTORS



AN INDUCTOR IS SIMPLY A COIL OF WIRE.
SOMETIMES IT MAY SURROUND AN IRON CORE,
TO INCREASE MAGNETIC EFFECTS. ITS
ELECTRIC SYMBOL IS:

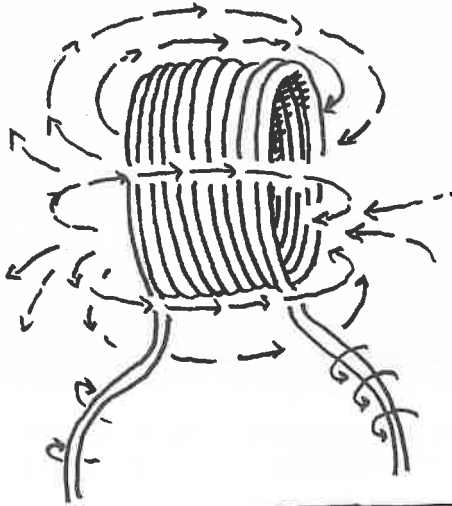


INDUCTOR **L**

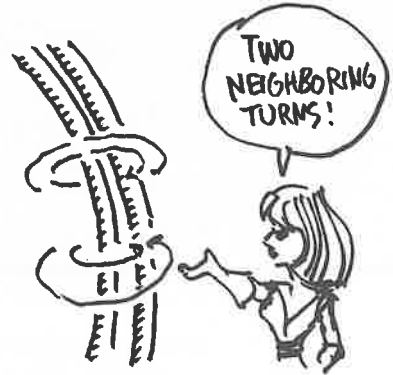


INDUCTOR **L** WITH
IRON CORE.

IF A CURRENT FLOWS THROUGH AN INDUCTOR, A MAGNETIC FIELD WILL SURROUND IT, AS WE'VE SEEN.



IF THE CURRENT IS CHANGED, MAGNETIC FIELD LINES CUT ACROSS THE TURNS OF THE COIL, PRODUCING A **SELF-INDUCTANCE** EFFECT.



BY LENZ'S LAW, THE INDUCED EMF OPPOSES THE CHANGE THAT PRODUCED IT. IF YOU TRY TO TURN ON THE CURRENT IN THE COIL, THE SELF-INDUCED EMF RESISTS, AND THE CURRENT CAN ONLY BUILD UP SLOWLY. IF YOU TRY TO TURN IT OFF, THE SELF-INDUCED EMF TRIES TO KEEP THE CURRENT FLOWING.

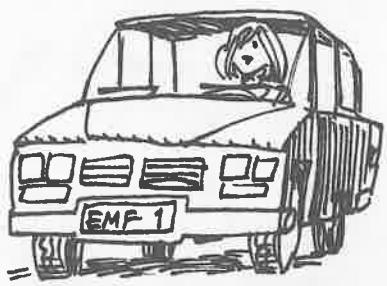


THESE EMFs CAN BUILD UP TO THOUSANDS OF VOLTS. FOR EXAMPLE, WHEN YOU OPEN A SWITCH, THIS EMF CAN SHOOT A SPARK THROUGH THE AIR, KEEPING THE CURRENT FLOWING FOR A MOMENT.

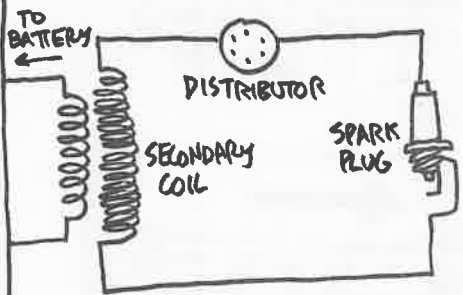
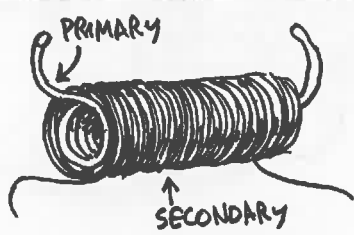




THE EFFECT IS EXPLOITED IN THE IGNITION CIRCUIT OF AN AUTOMOBILE.



THE "COIL" HAS TWO WINDINGS, A PRIMARY WINDING OF, SAY, A HUNDRED TURNS OF MEDIUM-SIZED WIRE, AND A SECONDARY WINDING OF THOUSANDS OF TURNS OF FINE WIRE. THE PRIMARY IS ENERGIZED THROUGH THE "POINTS" BY THE 12-VOLT BATTERY. WHEN THE POINTS OPEN, SWITCHING OFF THE CURRENT IN THE PRIMARY, THE COLLAPSING MAGNETIC FIELD INDUCES CURRENT IN THE SECONDARY. THE MANY TURNS AMPLIFY THE INDUCED EMF, AND GENERATE A MOMENTARY PULSE OF NEARLY **50,000 VOLTS!!**



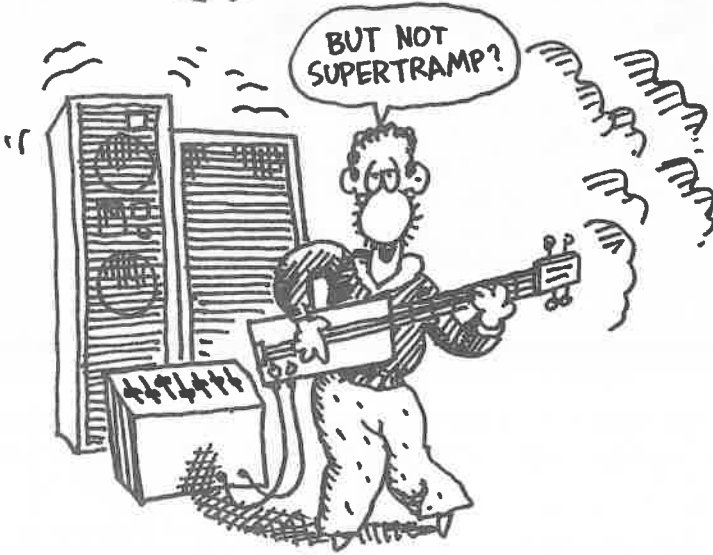
THIS IS DIRECTED BY THE DISTRIBUTOR TO THE SPARK PLUGS, PRODUCING A SPARK WHICH IGNITES THE GASOLINE. IN THIS WAY, A 12-VOLT BATTERY IS AMPLIFIED TO A HIGH-VOLTAGE SPARK.



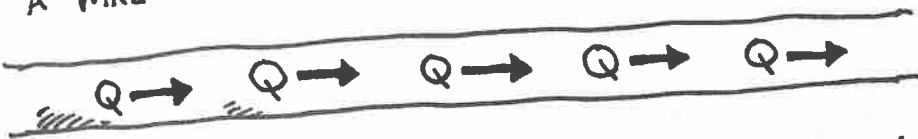
*MODERN IGNITION SYSTEMS USE ELECTRONIC SWITCHES.

CHAPTER 22

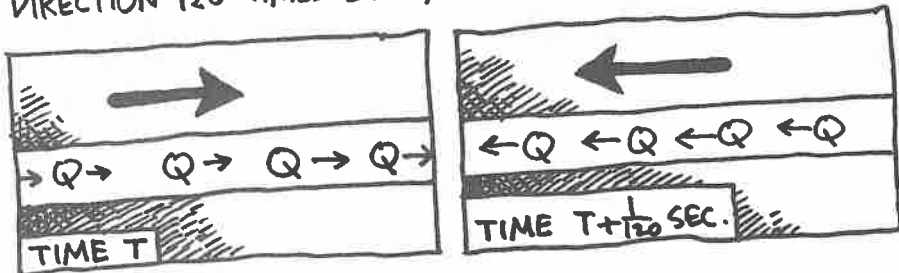
AC AND DC



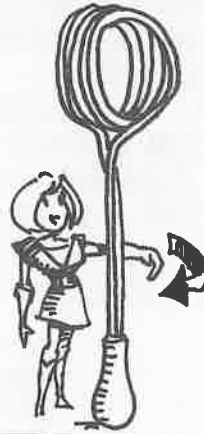
SO FAR WE'VE BEEN LOOKING ONLY AT **DC** — DIRECT CURRENT. A FLOW OF CHARGE IN ONE DIRECTION DOWN A WIRE.



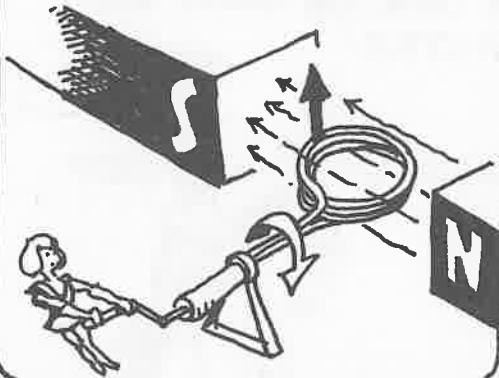
BUT WE USUALLY USE **AC** — ALTERNATING CURRENT, IN WHICH THE FLOW IS CONSTANTLY CHANGING DIRECTION. IN YOUR HOUSE WIRING, WHICH IS AC, IT REVERSES DIRECTION 120 TIMES EVERY SECOND!



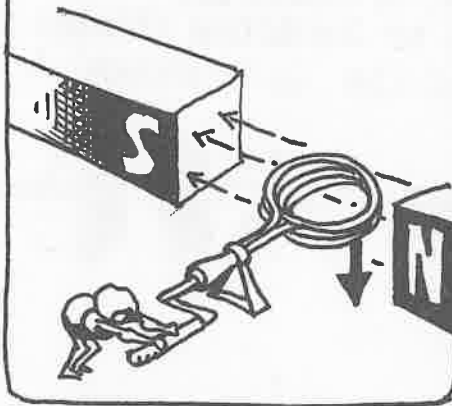
I CAN GENERATE AN ALTERNATING CURRENT BY SPINNING THIS EGGBEATER-LIKE INDUCTOR IN A PERMANENT MAGNETIC FIELD. IT DEVELOPS A CURRENT AS IT CUTS ACROSS THE MAGNETIC FIELD LINES.



THE CURRENT ALTERNATES BECAUSE THE LOOP CUTS THE FIELD LINES FIRST ONE WAY...



..AND THEN THE OTHER, A HALF TURN LATER.



THE AC THUS GENERATED CAN BE TAKEN OFF BY SLIP RING "BRUSHES." THIS IS HOW MOST OF OUR ELECTRIC POWER IS GENERATED.



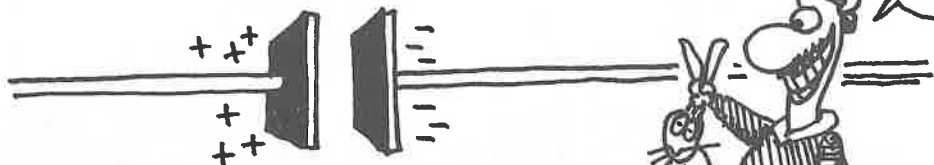
CAPACITORS AND INDUCTORS HANDLE AC AND DC DIFFERENTLY. THE INDUCED EMF IN AN INDUCTOR OPPOSES CHANGES IN CURRENT FLOWING IN IT. SINCE AC IS ALWAYS CHANGING, THE INDUCTOR RESISTS THE FLOW OF AC.



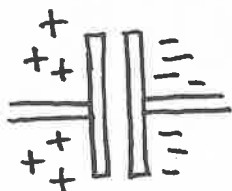
STOP!
STOP!

ON THE OTHER HAND, DC FLOWS RIGHT THROUGH AN INDUCTOR.

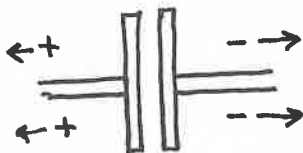
DC, OF COURSE, WON'T FLOW THROUGH A CAPACITOR—THERE IS NO CONNECTION BETWEEN THE CAPACITOR PLATES. BUT AC CAN "GET THROUGH" A CAPACITOR!



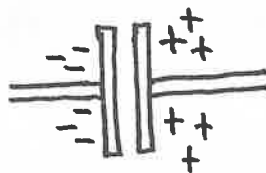
IT WORKS LIKE THIS: CHARGE MOVES BACK AND FORTH IN THE CIRCUIT, ALTERNATELY CHARGING A PLATE, DISCHARGING IT, AND RECHARGING IT THE OPPOSITE WAY. THE CURRENT APPEARS TO CROSS THE GAP.



1.

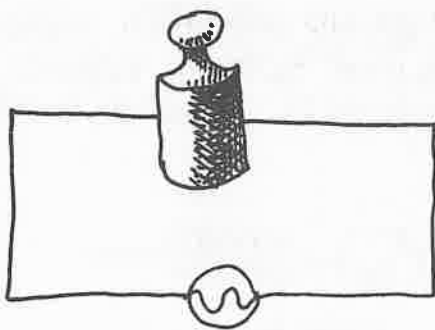


2.



3.

AN INDUCTOR'S RESISTANCE TO AC GIVES IT A KIND OF INERTIA. IN FACT, AN INDUCTOR IS AN ELECTRICAL ANALOG OF A MASS.

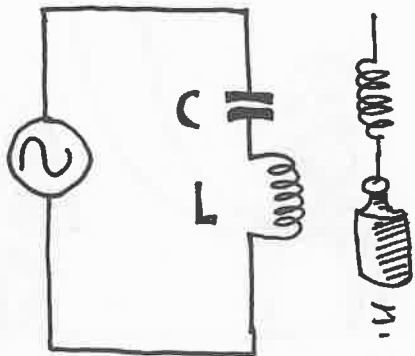


IF AN INDUCTOR IS MASSLIKE, A CAPACITOR IS SPRINGY. WHEN YOU TRY TO PUMP CHARGE TO AN ALREADY CHARGED PLATE, IT PUSHES BACK—LIKE A SPRING.

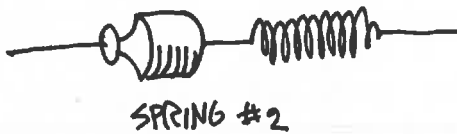
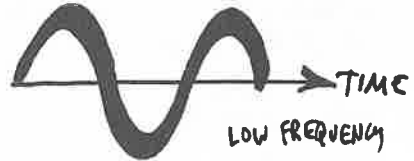
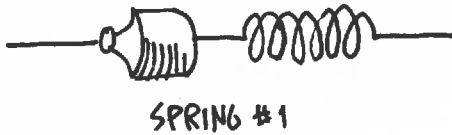
CAPACITOR
REPELS ADDED
CHARGE

SPRING REPELS
ADDED PRESSURE

CONNECT AN INDUCTOR AND A CAPACITOR IN AN AC CIRCUIT, AND YOU HAVE THE ELECTRICAL EQUIVALENT OF — A MASS ON A SPRING!

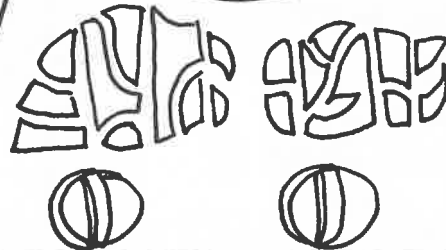


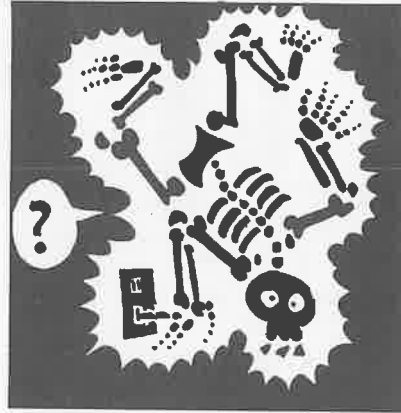
LIKE A SPRING AND MASS, THESE LC CIRCUITS TEND TO VIBRATE AT A PREFERRED ("RESONANT") FREQUENCY.



SUCH A CIRCUIT CAN BE USED (WITH AN ENERGY SOURCE) TO GENERATE A SPECIFIC FREQUENCY, OR TO TUNE ONE IN, AS IN YOUR RADIO.

HELLO, AND WELCOME TO ANOTHER BORING PROGRAM FROM AN OBSOLETE MEDIUM...

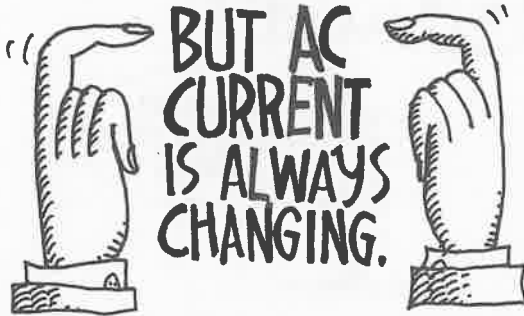
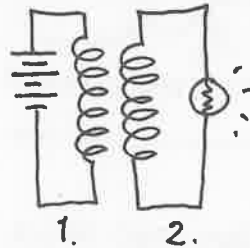




BECAUSE!



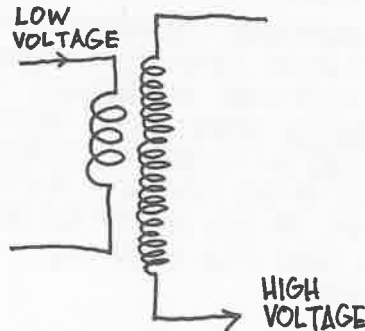
RECALL THE TWO INDUCTION COILS FROM THE FARADAY EXPERIMENT (OR FROM YOUR CAR STARTER). CURRENT WAS INDUCED IN COIL #2 ONLY WHEN THE CURRENT TO COIL #1 WAS TURNED ON OR OFF. ONLY CHANGING CURRENT CAN INDUCE CURRENT.

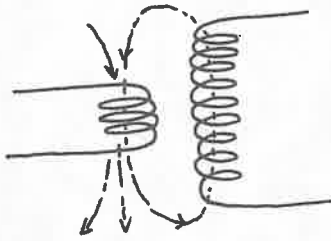


BUT AC CURRENT IS ALWAYS CHANGING.

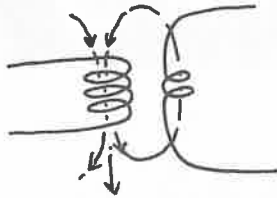


THE BEST PART IS THIS: THE INDUCED VOLTAGE IS PROPORTIONAL TO THE TURNS RATIO:
 THE MORE TURNS IN COIL #2, AS COMPARED TO COIL #1, THE HIGHER THE VOLTAGE INDUCED IN COIL #2!





STEPPING UP VOLTAGE



STEPPING DOWN VOLTAGE

IT IS NOT HARD TO SEE WHY: IN THE SECONDARY, THE MORE WIRE IS CUT BY THE CHANGING MAGNETIC FIELD LINES, THE MORE EMF IS GENERATED. IF

N_p = NUMBER OF TURNS IN PRIMARY

N_s = NUMBER OF TURNS IN SECONDARY

THEN

$$V_{OUT} = \frac{N_s}{N_p} V_{IN}$$

THE RESULTING DEVICE, FOR STEPPING VOLTAGE UP OR DOWN, IS CALLED A

TRANSFORMER

WITH THE SYMBOL



AND IT WORKS ONLY FOR AC.



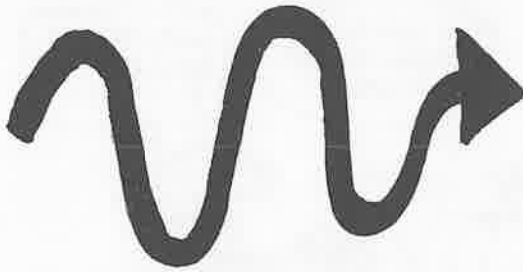
LOOKS LIKE VOLTAGE FROM NOWHERE?

A TRANSFORMER "TRANSFORMS" VOLTAGES UP OR DOWN — AND NO, YOU CAN'T GET SOMETHING FOR NOTHING. THE **POWER** OUTPUT OF THE SECONDARY COIL CAN NOT EXCEED THE POWER INPUT OF THE PRIMARY. IN OTHER WORDS, AS YOU STEP UP THE VOLTAGE, YOU MUST STEP DOWN THE CURRENT.

$$P_{OUT} = V_{OUT} i_{OUT} \leq P_{IN} = V_{IN} i_{IN}$$

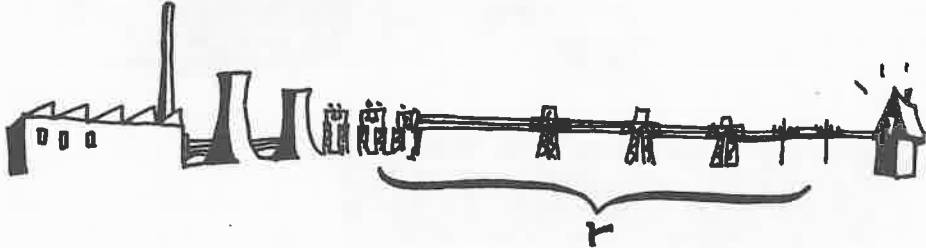


CONSERVATION OF ENERGY? YOU BET!



THIS, THEN, IS THE GREAT ADVANTAGE OF ALTERNATING CURRENT: ITS VOLTAGE CAN BE EASILY STEPPED UP OR DOWN.

THIS IS ESPECIALLY IMPORTANT BETWEEN POWER GENERATING STATIONS AND THE CUSTOMERS THEY SERVE:

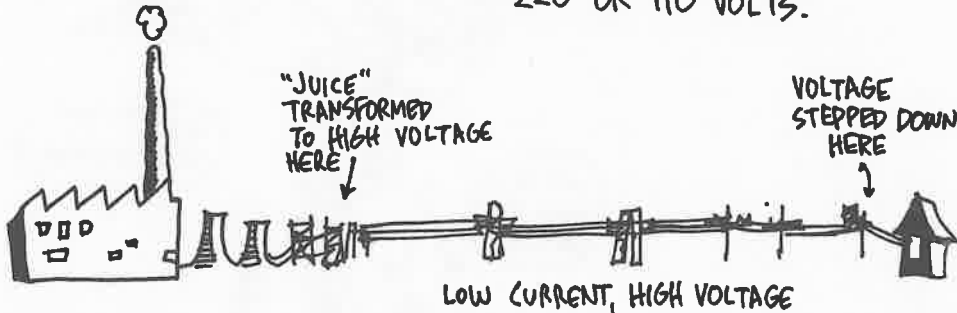


THE TRANSMISSION WIRES HAVE A RESISTANCE R , SO THERE IS A VOLTAGE DROP $V = iR$ AND POWER LOSS $P = iV = i^2R$ ALONG THE LINE. AT HIGH CURRENT i , ENORMOUS AMOUNTS OF POWER ARE WASTED.



THAT'S WHERE TRANSFORMERS COME IN!

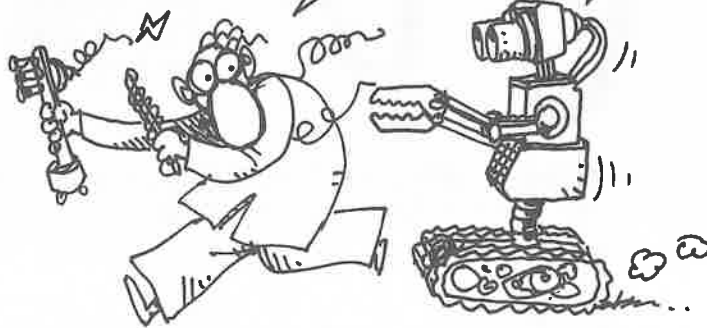
BY STEPPING UP TO VERY HIGH VOLTAGE (MORE THAN 100,000 VOLTS!) AT THE SOURCE, CURRENT IS REDUCED IN THE WIRES, AND THE POWER LOSS IS MINIMIZED. THEN, AT THE USER'S END, VOLTAGE IS STEPPED DOWN TO A RELATIVELY SAFE 220 OR 110 VOLTS.



OUR HUGE ELECTRIC
POWER SYSTEM IS
ALL DUE TO THE
HUMBLE TRANSFORMER.

BUT WATCH FOR
TECHNOLOGICAL
PROGRESS!

STOP... WAIT... I
ONLY WANT TO
KILL YOU...



WITH THE INVENTION OF HIGH-TEMPERATURE
SUPERCONDUCTORS
AND HIGH-TECH DEVICES FOR TRANSFORMING
DC VOLTAGES, WE MAY SEE SOME
DC POWER LINES IN COMING DECADES.

