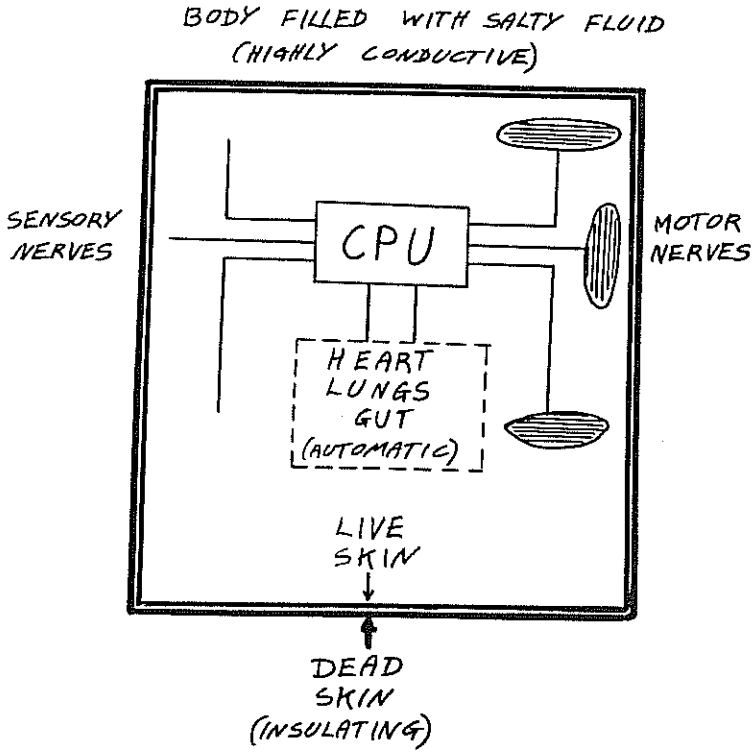
# LECTURES ON ELECTRICAL SAFETY

Dr Martin Fry

martin.fry@ucl.ac.uk

# AN ELECTRONIC ENGINEER'S VIEW OF THE BODY



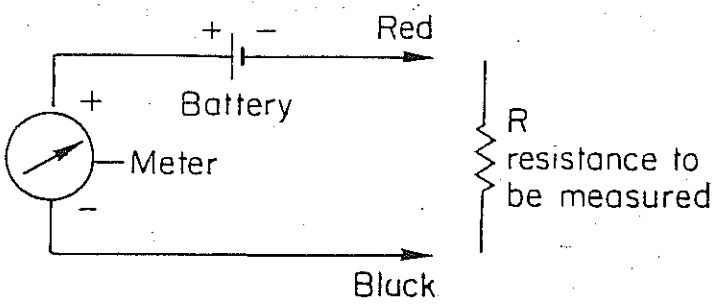

## EFFECTS OF ELECTRICITY ON THE BODY

1. **NEURO-MUSCULAR EFFECTS**
   - A. Sensory nerves – pain, smell, taste, etc
   - B. Motor nerves – muscle contraction
   - C. Muscles - contraction
2. **HEATING**
3. **ELECTROLYSIS**

### 1. NEURO-MUSCULAR EFFECTS

| | |
|---|---|
| 1mA | Perception |
| 10mA | Can't let go |
| 100mA | Severe pain and interference to heart and chest function |
| 1A | Sustained heart contraction |

## HOW DOES AN OHMMETER WORK ?




- Meter gives deflection ∝ current
- Calibrated from Ohm's law

- Zero resistance gives full scale reading
- Infinite resistance gives no deflection

- Switchable series resistors - select ranges
- Values between 1R and 10M measurable

## CURRENT THROUGH SKIN @ 230 V

| | R | I |
|---|---|---|
| SWEAT ↓ | 100 000 | 2.3 mA |
| | 10 000 | 23 mA |
| | 5000 | 46 mA |
| | 1000 | 230 mA |

# SKIN AND BODY RESISTANCE

## Skin resistance:

1. Limits current that can flow through the body
2. Varies widely depending on:
    - Part of body
    - Water (liquid, moisture or sweat)
    - Natural oil present
    - Intact or broken
3. Inversely proportional to the area of contact

## Resistances of body & connections at 50Hz:

Skin: $15k\Omega.cm^2$ to $1M\Omega.cm^2$
Limb: $200\Omega$
Trunk: $100\Omega$
Liquid-filled catheters: $50k\Omega$ to $1M\Omega$
Electrodes: (Ag/AgCl): $500\Omega$

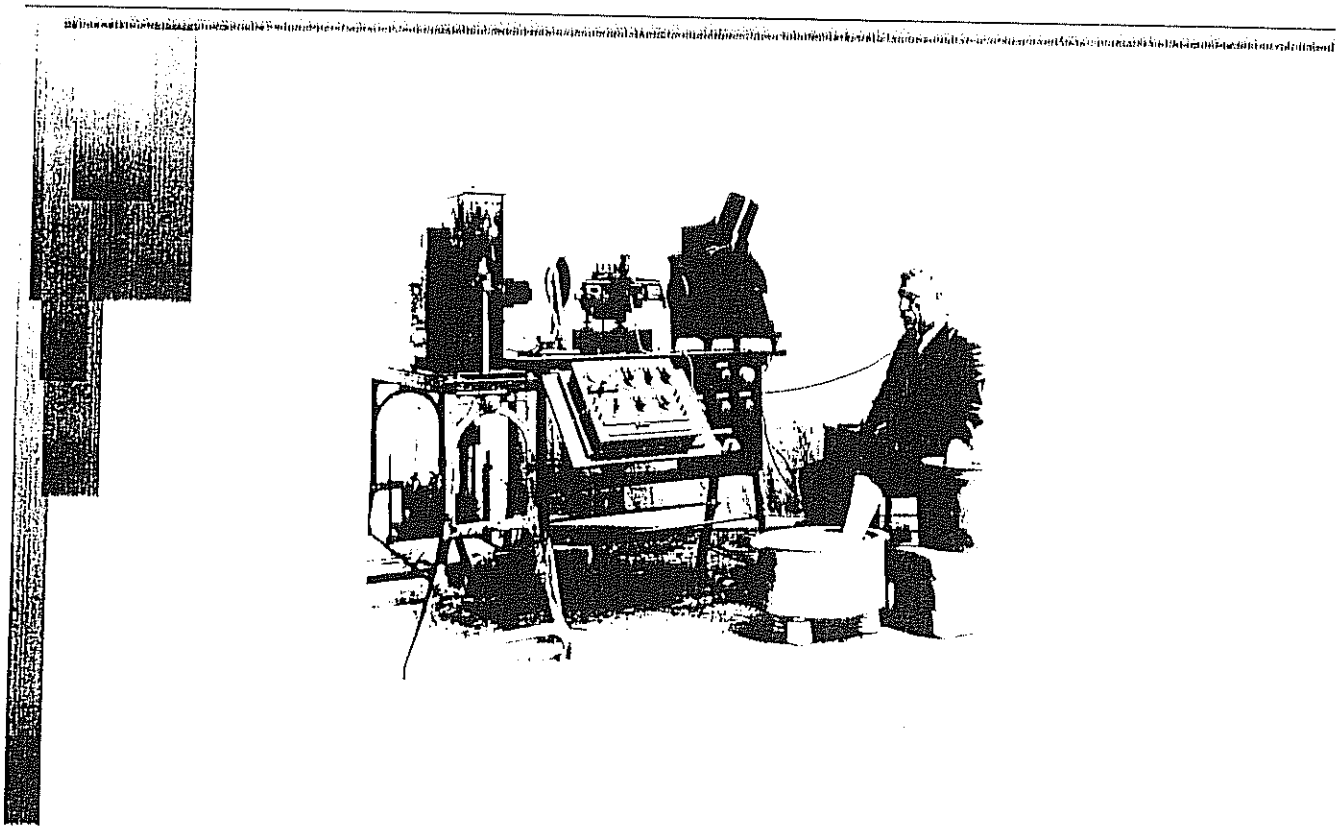
## Copper handles example:

Diameter: 22mm
Length of skin in contact: 7cm
Area of skin in contact: $\pi.D.L = \pi \times 0.22 \times 7cm$
$= 4.8cm^2$
Skin Resistance: $\frac{15k\Omega.cm^2}{4.8cm^2}$ to $\frac{1M\Omega.cm^2}{4.8cm^2}$

$= 3k\Omega$ to $200k\Omega$

John Webster (1998), "Medical Instrumentation: Application and Design (3rd edition)", p.634

# *The First Electrocardiograph Machine*





It consists of a large chair, in which the patient sits, provided with four troughs or buckets in which carbon electrodes are secured, and a switchbound board of

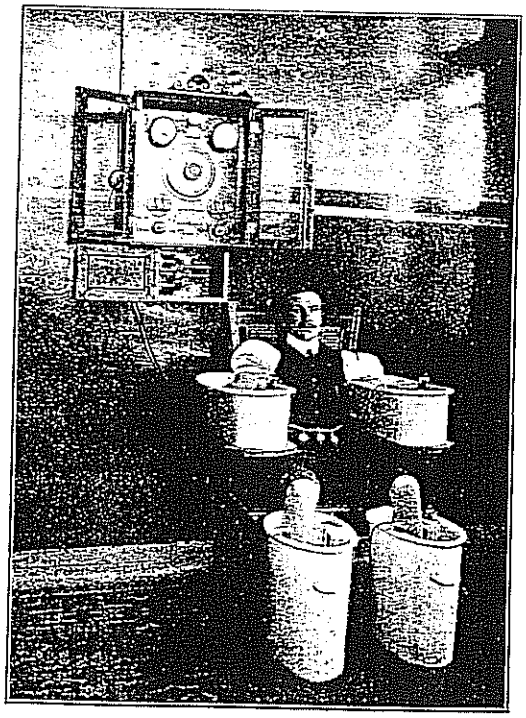


Fig. 69. Dr. Schneè's Bath.

special design. The regulation is by means of a shunt resistance. In the lower part is a small motor, on the shaft on which are mounted a series of commutators and

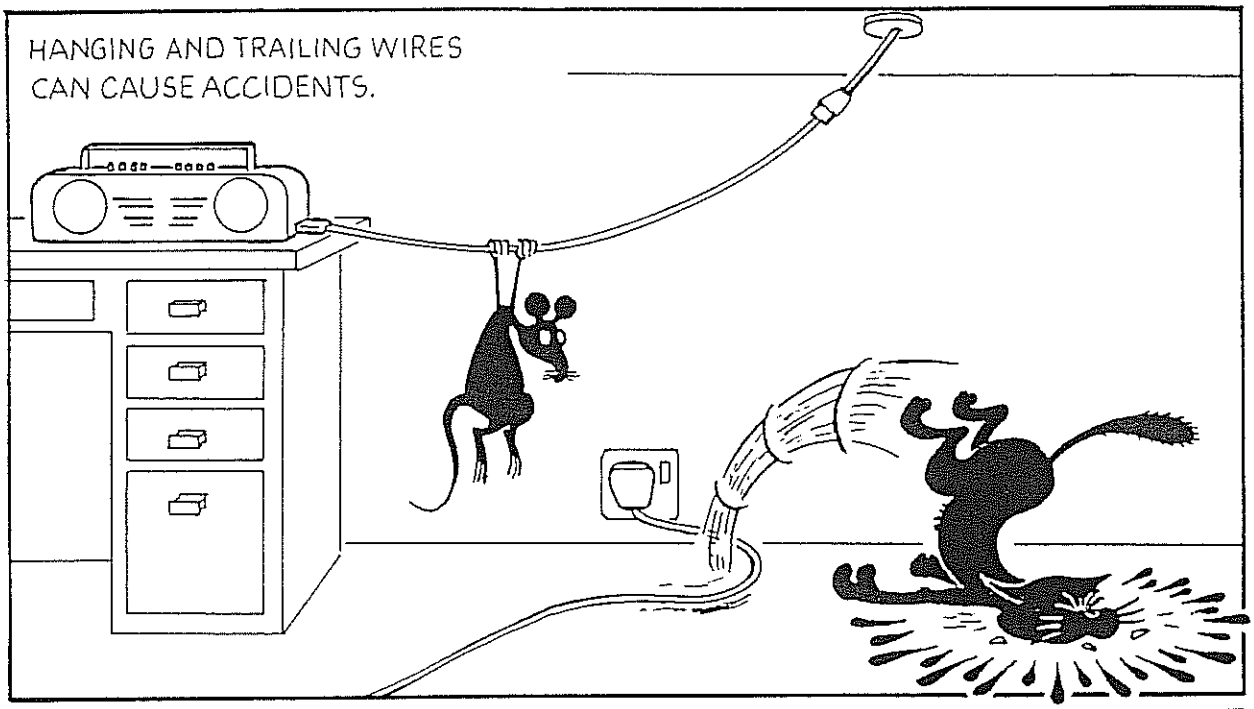


switch close by makes the current supplied to the board constant or sinusoidal as required. Instead of two arms, an arm and a leg may be immersed or both arms and both legs.

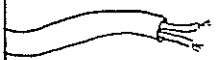
Fig. 68. Arm Bath.

The most highly developed form of the monopolar bath is that designed by Dr. Schneè, which is shown in figure 69.

HANGING AND TRAILING WIRES
CAN CAUSE ACCIDENTS.

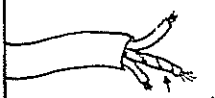


ELECTRICAL EQUIPMENT
MUST BE EARTHED
UNLESS IT IS DOUBLE INSULATED



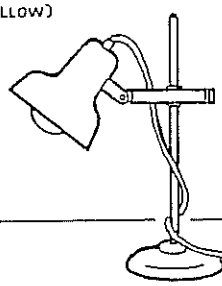
TWO-CORE FLEX
FOR DOUBLE-INSULATED
EQUIPMENT ONLY.

SIGN FOR
DOUBLE
INSULATION.



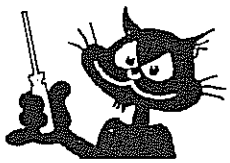
ALL OTHER EQUIPMENT
NEEDS THREE-CORE FLEX.

EARTH WIRE (GREEN AND YELLOW)



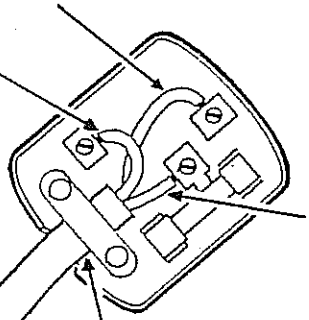
IS YOUR EQUIPMENT
EARTHED?

FIT PLUGS CORRECTLY
FOR SAFETY.



EARTH WIRE
(GREEN AND YELLOW)

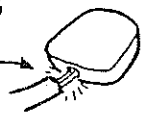
NEUTRAL
WIRE
(BLUE)



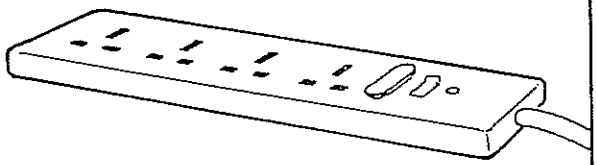
LIVE
WIRE
(BROWN)

OUTER COVERING
INSIDE CORD GRIP.

NOT LIKE THIS



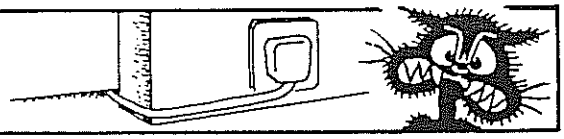
TO POWER FOUR 3-AMP LAMPS, COMPUTERS, ETC.
FROM ONE 13-AMP SOCKET, USE A
FUSED DISTRIBUTION BOARD.




USE THE CORRECT FUSE
FOR YOUR EQUIPMENT:

3 AMP UP TO 750 WATTS
5 AMP UP TO 1200 WATTS
13 AMP UP TO 3000 WATTS

TAKING POWER FROM OUTSIDE THE ROOM
CAN CAUSE TROUBLE (IT INTERFERES WITH THE WORK OF CLEANING AND MAINTENANCE).



# DOCTOR FRY'S DOCTORED AND FRIED LEAD VISUAL INSPECTION LAB NOTES

## "My worst work ever!"

In hospitals, most problems with the use of medical electrical equipment are associated with the mains plug and lead.

The object of this practical session is to examine a number of mains leads and by visual inspection alone identify:

- Faults
- Possible hazards which would arise if the leads were used
- Non-compliance with BS EN 60601-1
- Recommendations to rectify faults, hazards and non-compliance

**THE NUMBER ONE RULE OF MEDICAL PHYSICS:**

"YOU MUST NOT KILL THE PATIENT (OR YOURSELF OR ANYONE ELSE)"

These mains leads all have not less than 5 faults; some are:

- Blatantly obvious and really dumb
- Potentially lethal
- Subtle, but nevertheless fail to comply with BS EN 60601-1

The faults may have arisen by:

- Misuse, abuse or damage
- Improvised "Ingenious repairs" by unqualified staff
- Sabotage

Your task is to spot all the faults you can simply by VISUAL INSPECTION.

Do NOT under any circumstances attempt to test these cables by plugging them into a mains socket or any test device.

You may ONLY use:

- Your Hands
- Your Eyes
- Your Brain
- A screwdriver

This practical session introduces you to:

**THE NUMBER TWO RULE OF MEDICAL PHYSICS:**

"THERE ARE LOTS OF WAYS TO GET THINGS WRONG – BUT USUALLY ONLY ONE WAY TO GET IT RIGHT !"

# OFFER SAFETY ADVICE REGARDING SETTING UP THE FAULTY LEAD LAB

# LEGAL ASPECTS

Under the Health and Safety at Work act all employees have a responsibility both to themselves, their colleagues, and their institution to ensure that they are not creating a situation that could lead to an accident, injury, or damage to property) either by act or omission). (See Health and Safety Executive, "Management of health and safety at work" L21 ISBN 0 7176 0412 8.)

**ASSEMBLY**

- At work - people "borrow" things without asking
- Tell colleagues what's being done
- Don't leave leads lying around – even momentarily to answer the telephone
- Label each lead: **DANGER: DO NOT USE**
- Possibly add a legal disclaimer notice to each lead

- If the assembly work is carried out at home, there may be small children around who may not be able to read warnings, but may nevertheless have a tendency to like "plugging in plugs"

**DURING THE PRACTICAL SESSION**

- The lecturer should give verbal instructions
- The lecturer should give written instructions
- In particular it should be emphasised: "Do **NOT** under any circumstances attempt to test these cables by plugging them into a mains socket or any test device."
- The lecturer must ensure all cables are returned – "Count them out and count then in".

**STORAGE**

- Store leads in a locked metal case
- Warning notice on case
- Store case in locked office
- Don't lend out to anyone

**BE PROACTIVE: SAVE LIVES !**

- The lecturer could encourage trainees to pass on to him any faulty cables they come across.
- The lecturer should encourage the trainees to be vigilant at home, at work and when visiting family, friends and relatives – by spotting cable faults, lives may be saved.

# LEAD VISUAL INSPECTION REPORT

| LEAD NO. | FAULT NO. | DESCRIPTION OF FAULTS, HAZARDS, NON-COMPLIANCE AND RECOMMENDATIONS |
|---|---|---|
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |

# LEAD VISUAL INSPECTION REPORT

| LEAD NO. | FAULT NO. | DESCRIPTION OF FAULTS, HAZARDS, NON-COMPLIANCE AND RECOMMENDATIONS |
|---|---|---|
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |

# LEAD VISUAL INSPECTION REPORT

| LEAD NO. | FAULT NO. | DESCRIPTION OF FAULTS, HAZARDS, NON-COMPLIANCE AND RECOMMENDATIONS |
|---|---|---|
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |

# LEAD VISUAL INSPECTION REPORT

| LEAD NO. | FAULT NO. | DESCRIPTION OF FAULTS, HAZARDS, NON-COMPLIANCE AND RECOMMENDATIONS |
|---|---|---|
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |