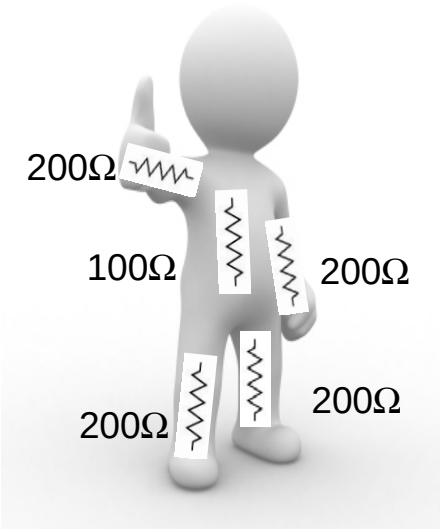
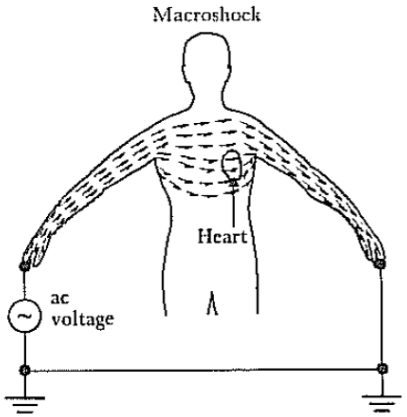
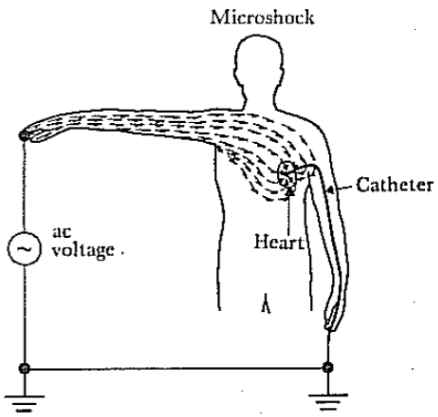
MPHYGB17: Electrical Safety
Second Lecture

Nick Donaldson
(Module Organiser)

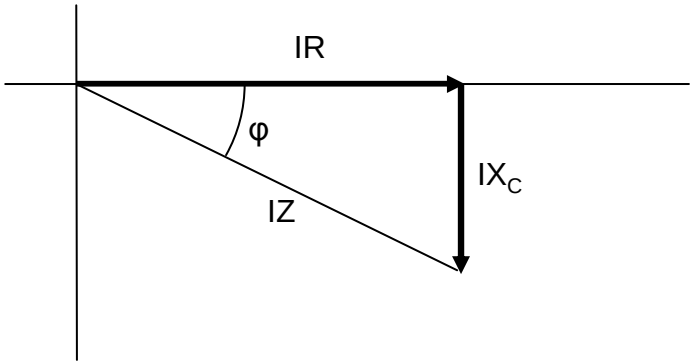
Last week: Effects of Electricity on the Body







Impedance: concept and calculations



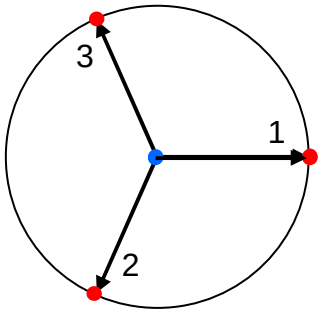
Moodle Quiz?

Mains Distribution, Protection and Macroshock

Electricity Distribution

Transformer with 3-phase (3-wire) input and 4-wire output:
Phase 1, Phase 2, Phase 3 & Neutral

3-phase supply:
120º phase difference



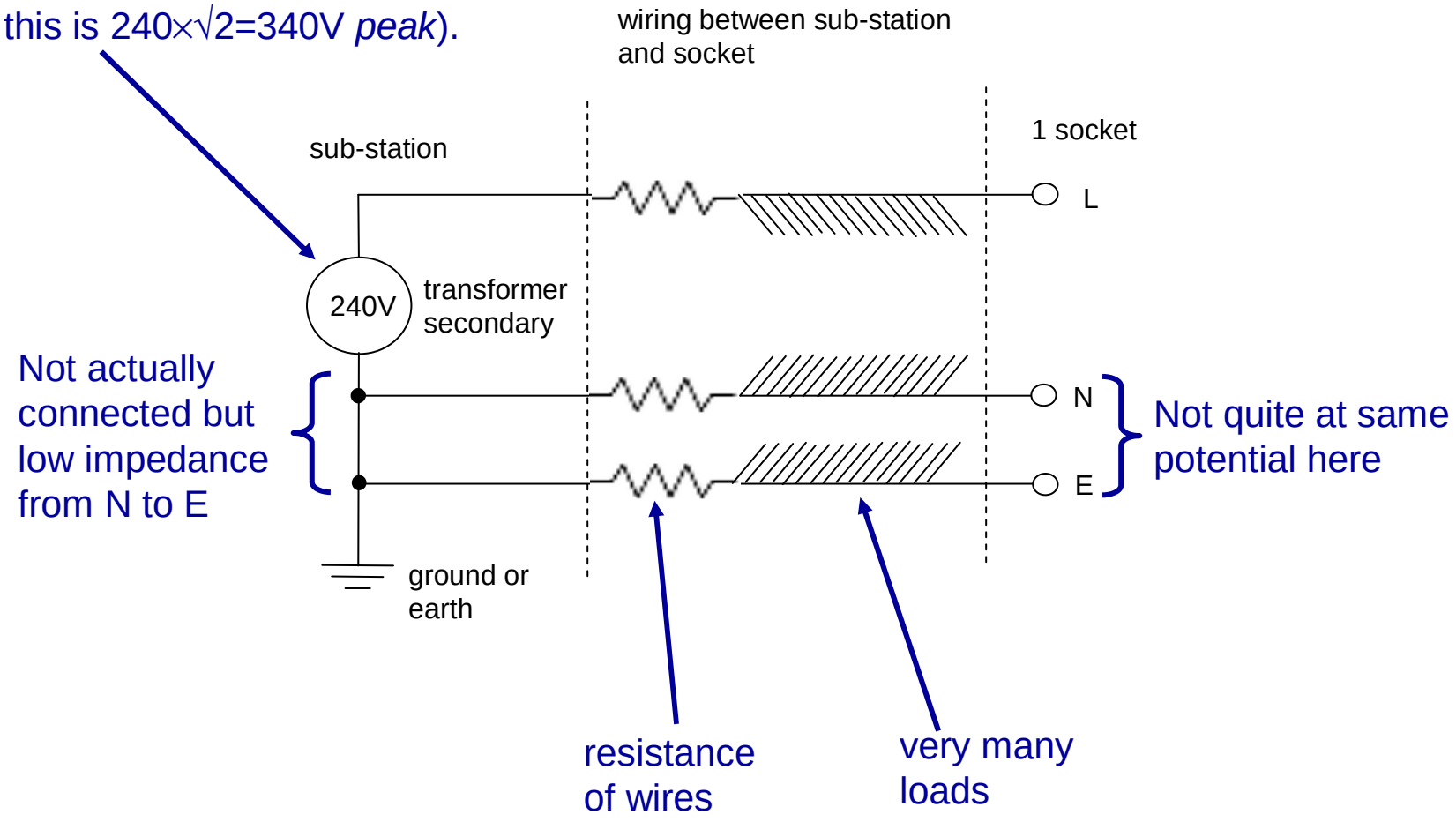
Usually, houses, hospital wards, etc are supplied by one phase, called *live*, plus *neutral* and an *earth* wire.

live
neutral
earth

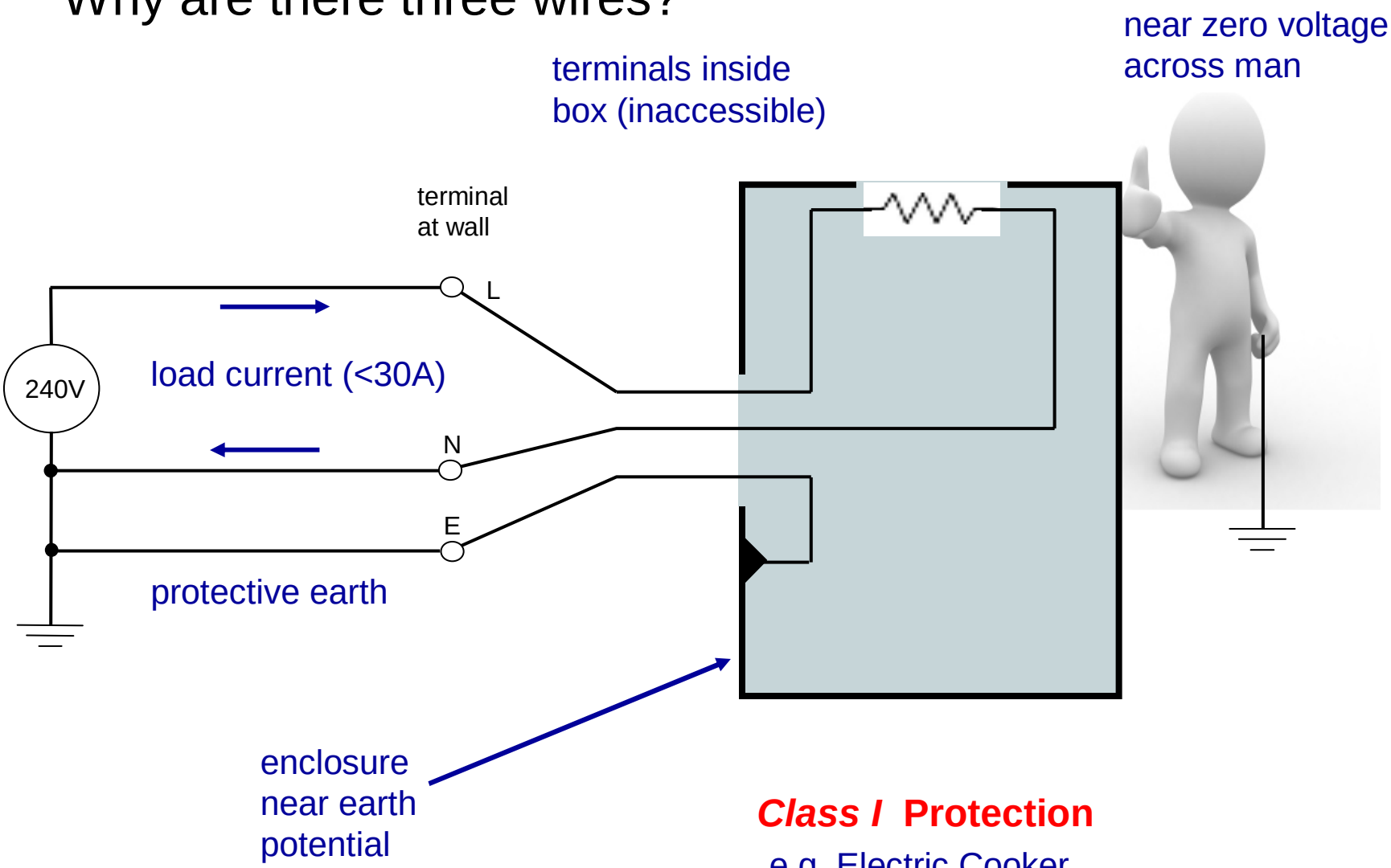
How should we regard the source?

240V (r.m.s.), 50Hz sinusoidal voltage source, grounded at one side.

(p.s. this is 240×√2=340V *peak*).



Why are there three wires?

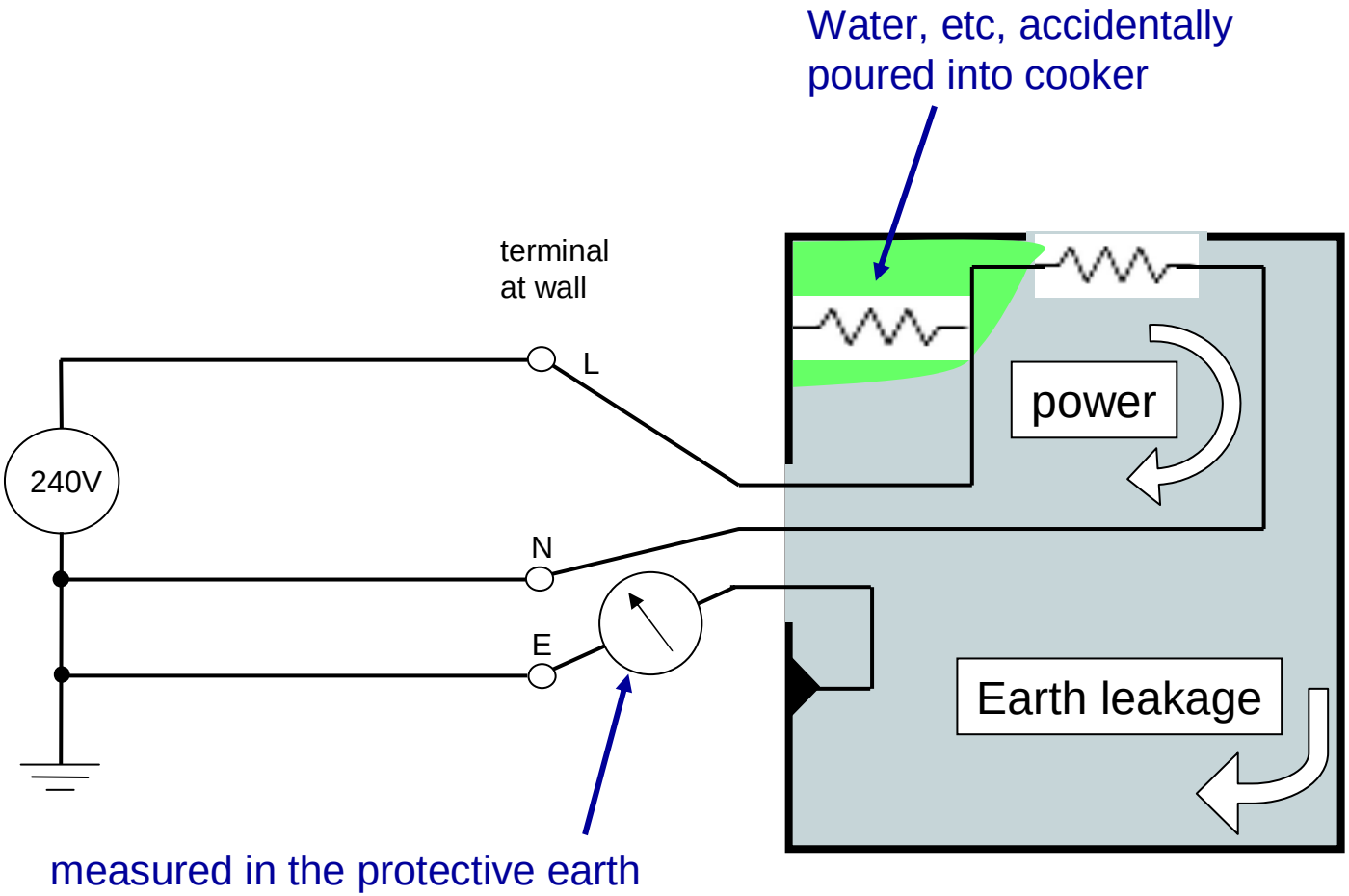


***Class I* Protection**

e.g. Electric Cooker

Why go to the expense of the 3rd wire?

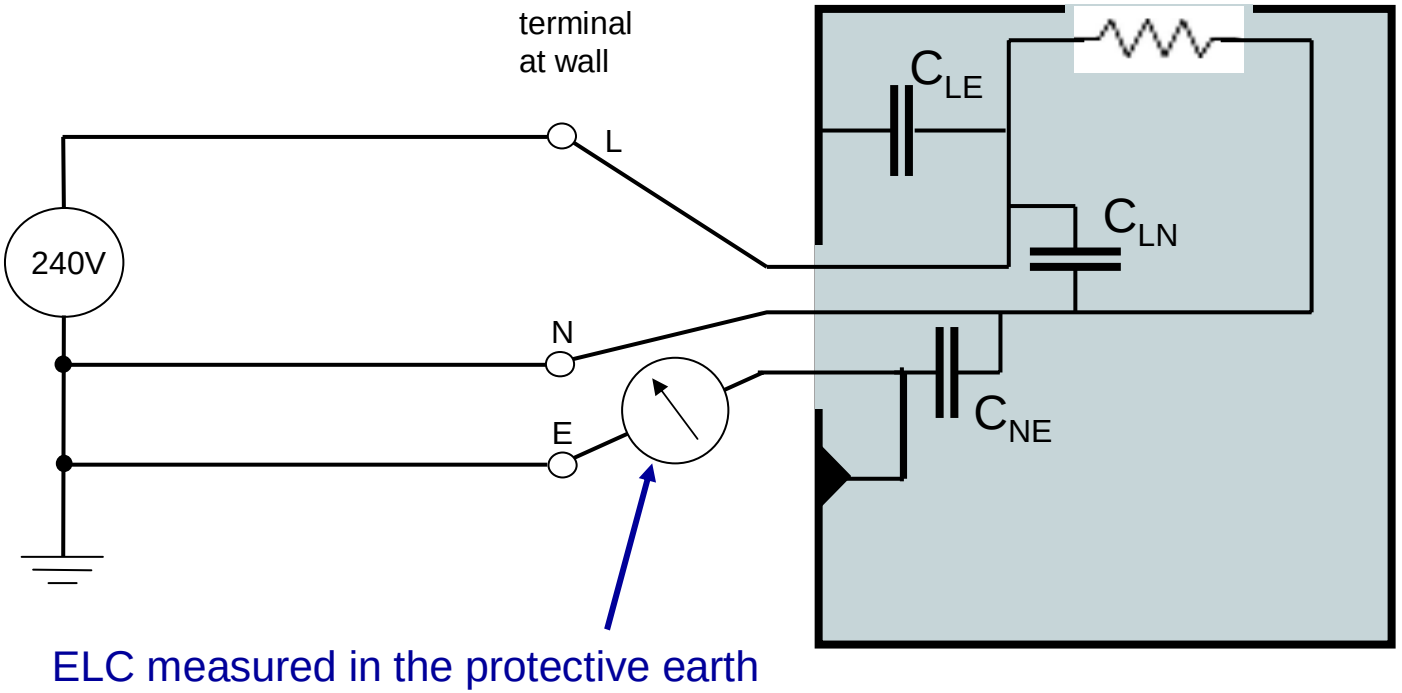
Earth Leakage Current (1)



Here: leakage current approximately in phase with mains voltage

Earth Leakage Current (2)

Filter capacitors

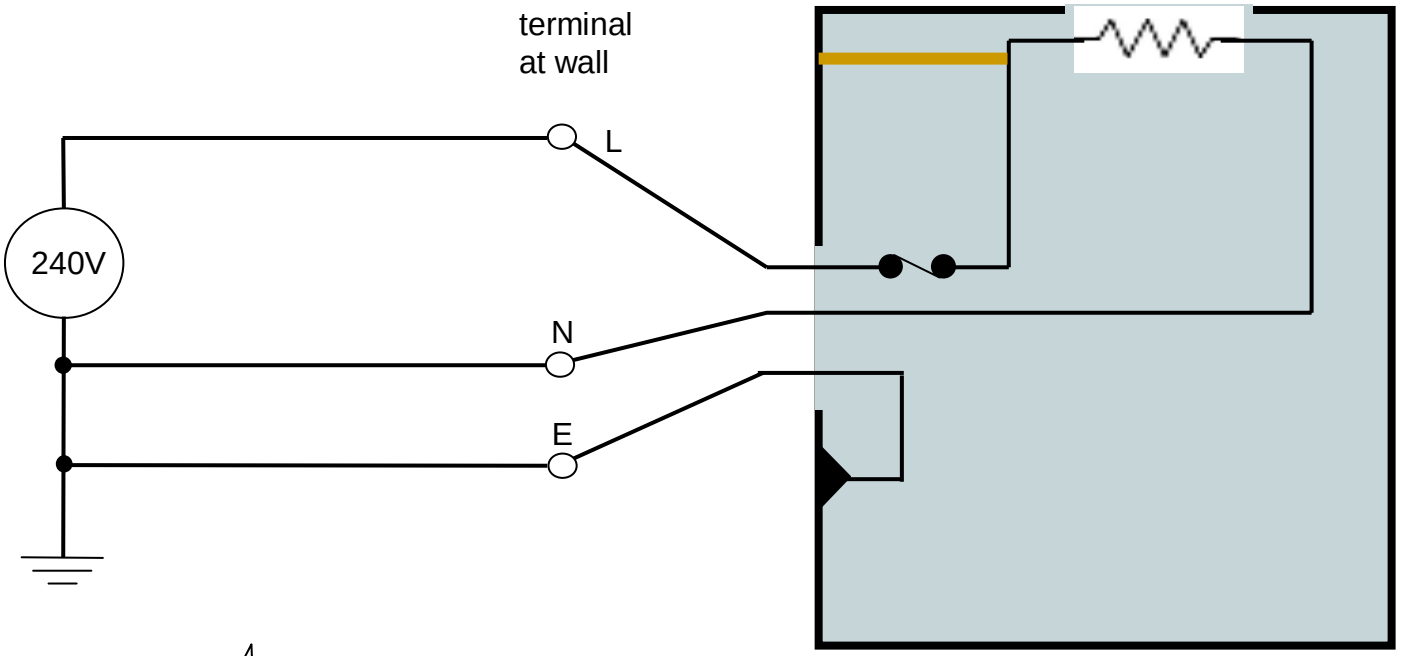


Here: leakage current approximately in quadrature with mains voltage

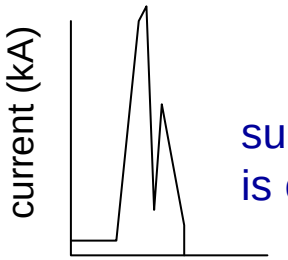
ELC measured in the protective earth

Which capacitor causes most ELC?

Earth Leakage Current (3)



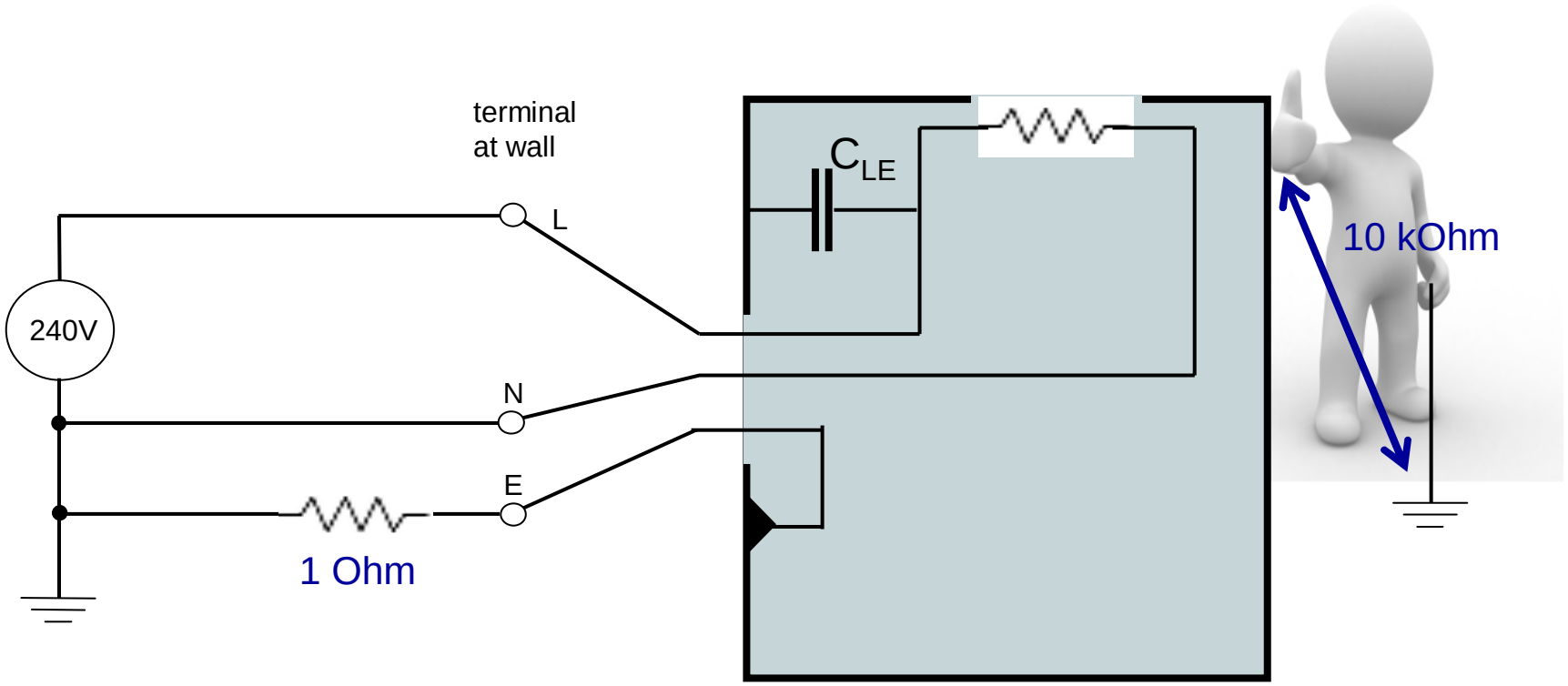
Short-circuit: broken insulator, loose connection, failed insulation on cable, loose metal parts, etc.



surge current is earth wire

Does the fuse prevent electric shock?

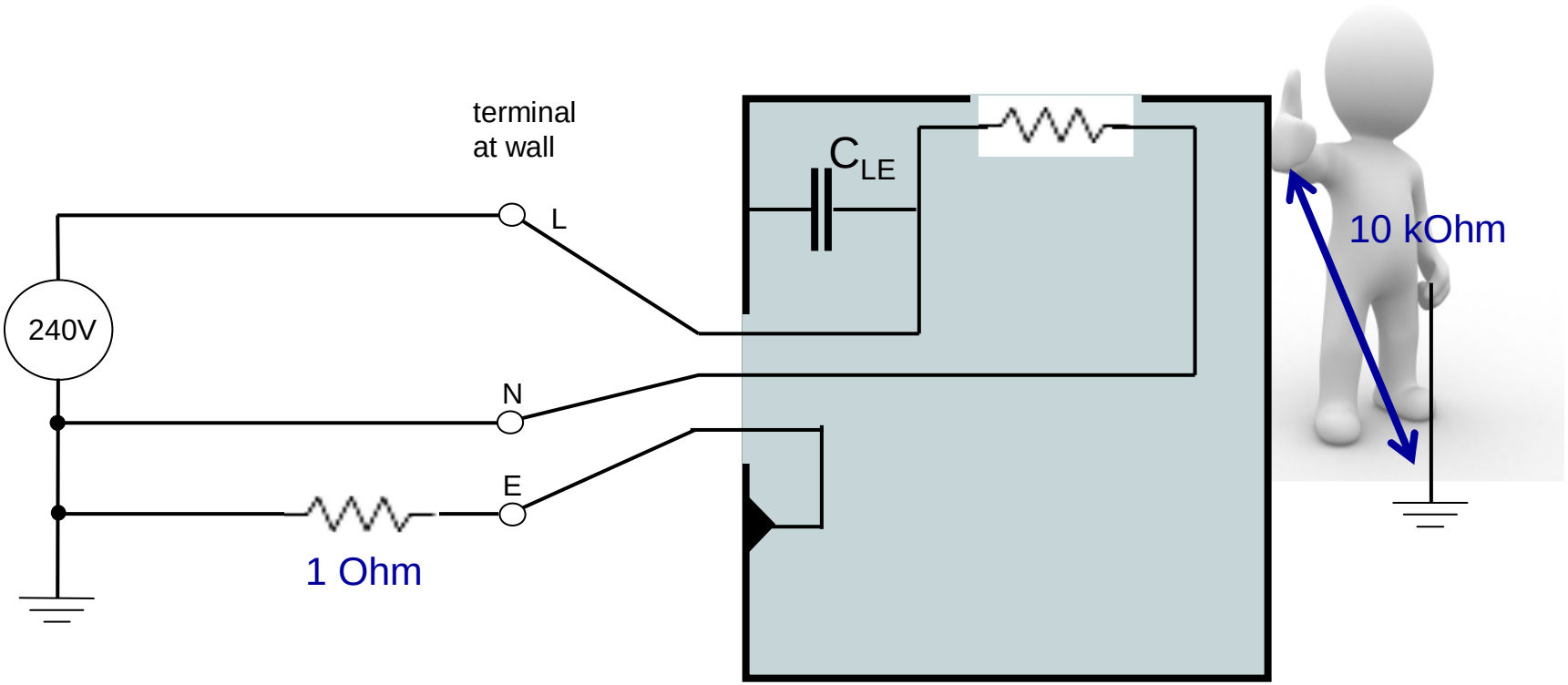
Two pathways to ground



If C_{LE} = 4.7nF, what current through the man?

X_C = 677kΩ, **ELC ≈ 240V / 677kΩ = 0.37 mA** **Man current = 0.037μA**

Fault Condition (1): broken protective earth

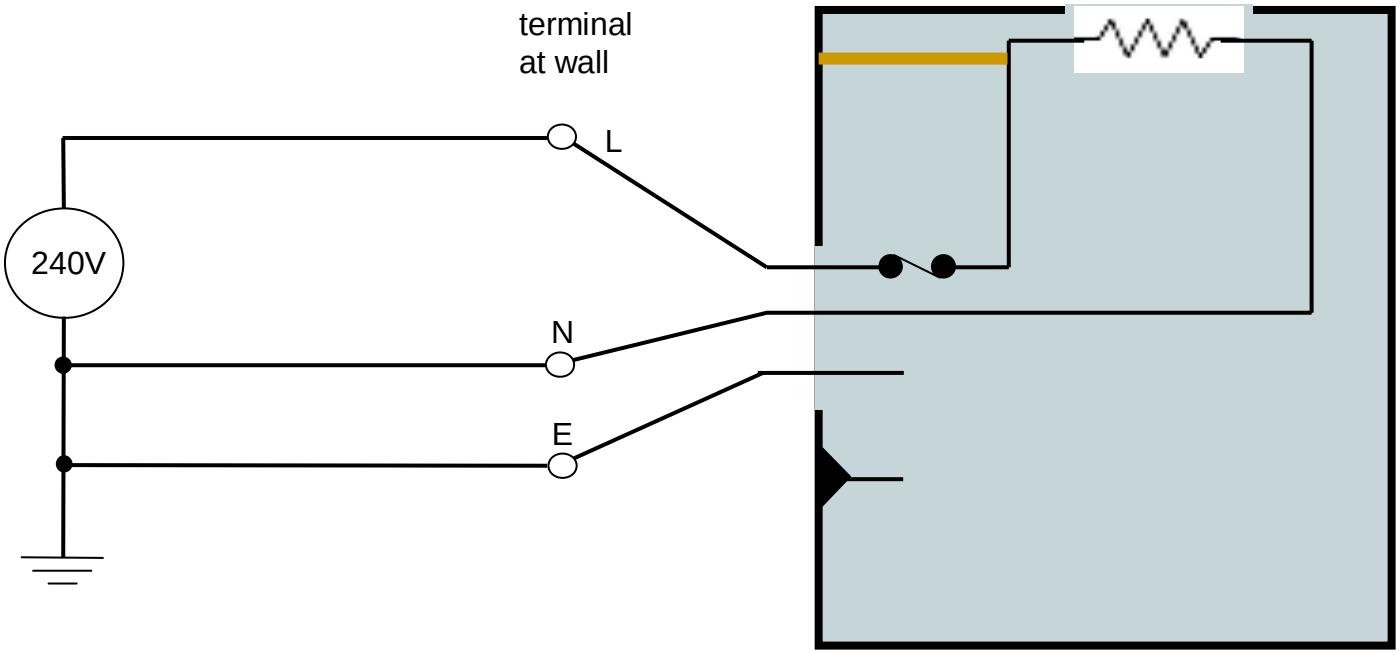


C_{LE} = 4.7nF still, what current through the man?

X_C = 677kΩ, **Man current ≈ 240V / 677kΩ = 0.37 mA**

What effect on the man?

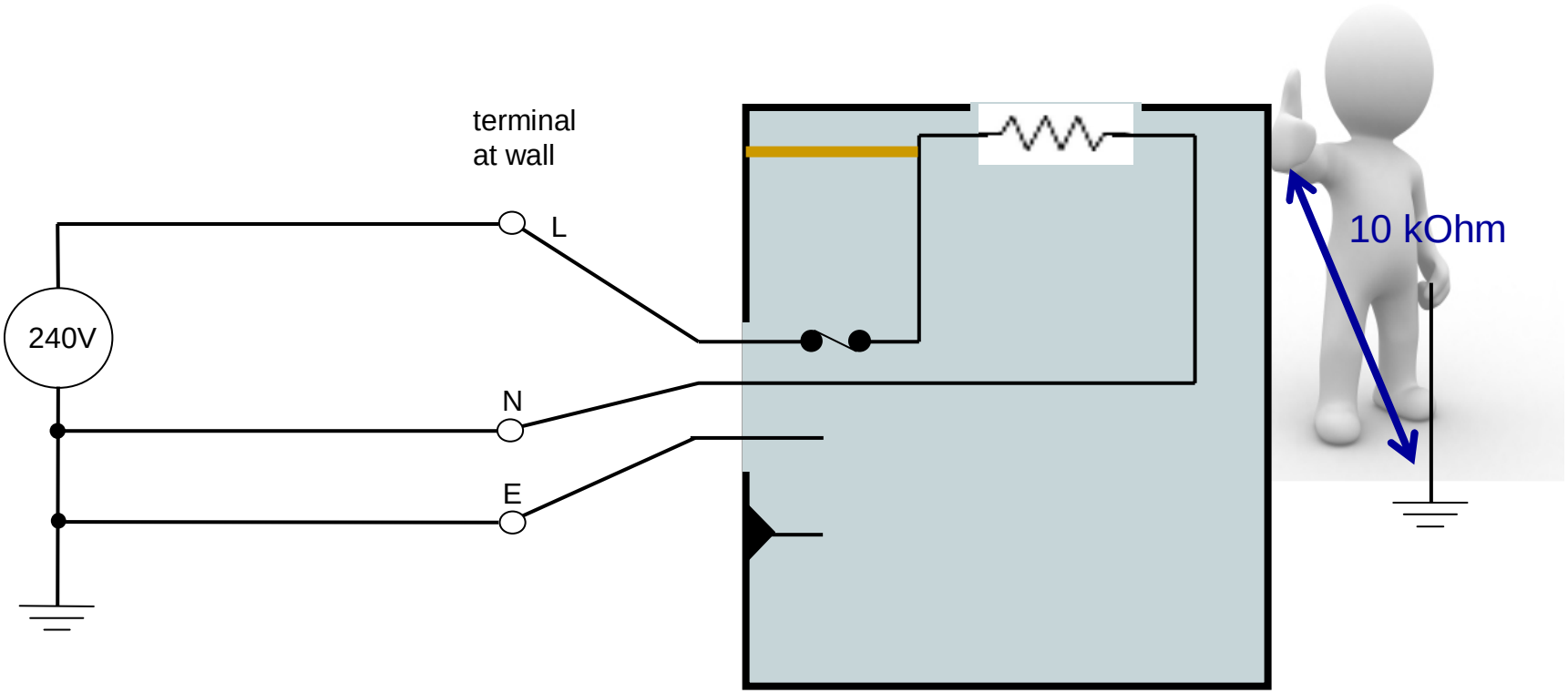
Fault Condition (2): broken protective earth, then short from live



Does the fuse blow?

What potential on the enclosure?

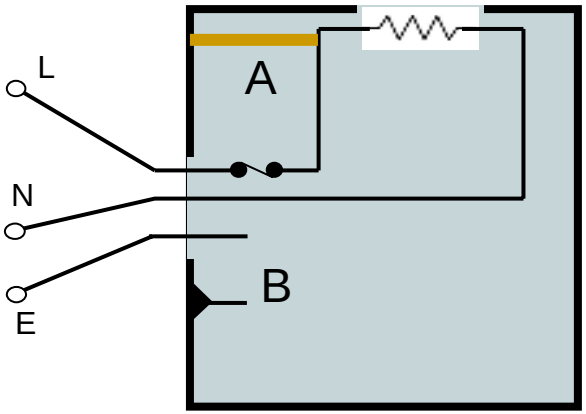
Fault Condition (3): enclosure live

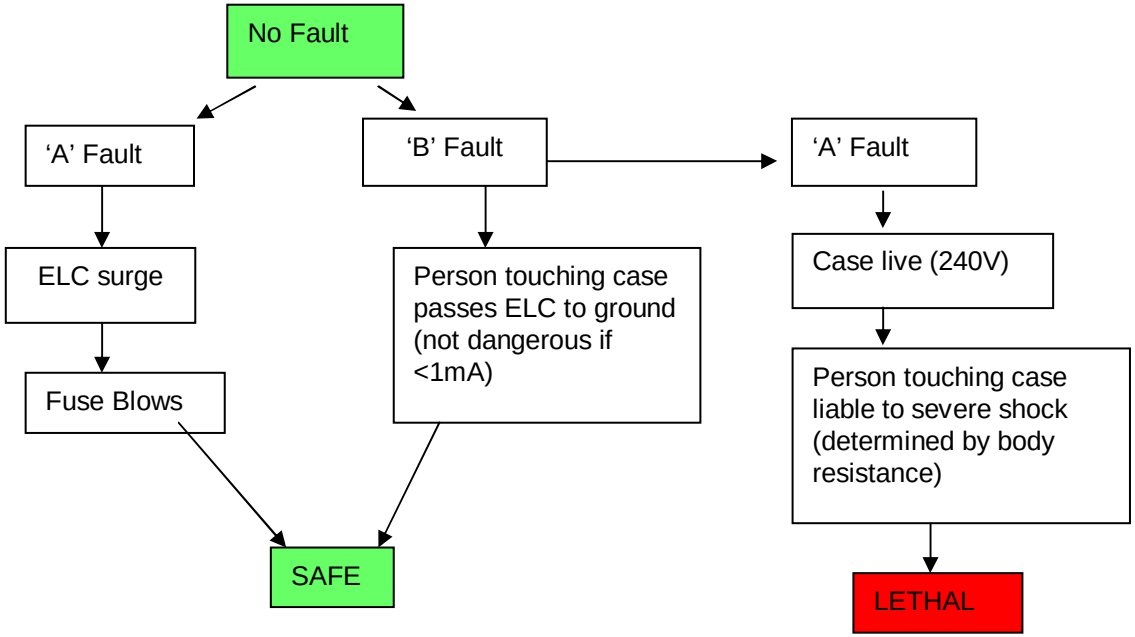


What current through the man?

Current no longer controlled by capacitive reactance but by resistance through man, which depends on contact area and wetness of the skin.

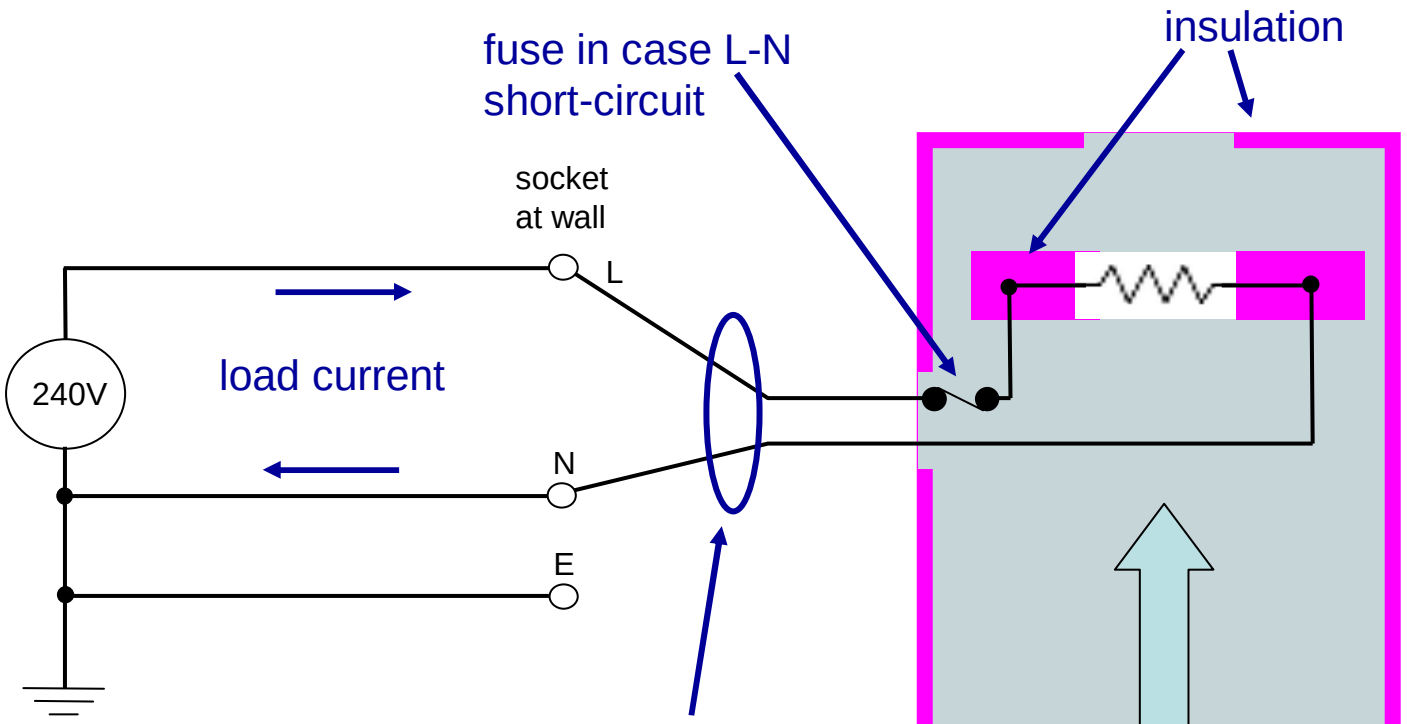
Fault Condition (4): Single- and Double-Fault Conditions





The distinction between single-fault conditions and double-fault or multiple-fault conditions is important. It is much easier to design so that equipment is safe under a list of single-fault conditions than after combined faults.

Class II Protection: Double Insulation

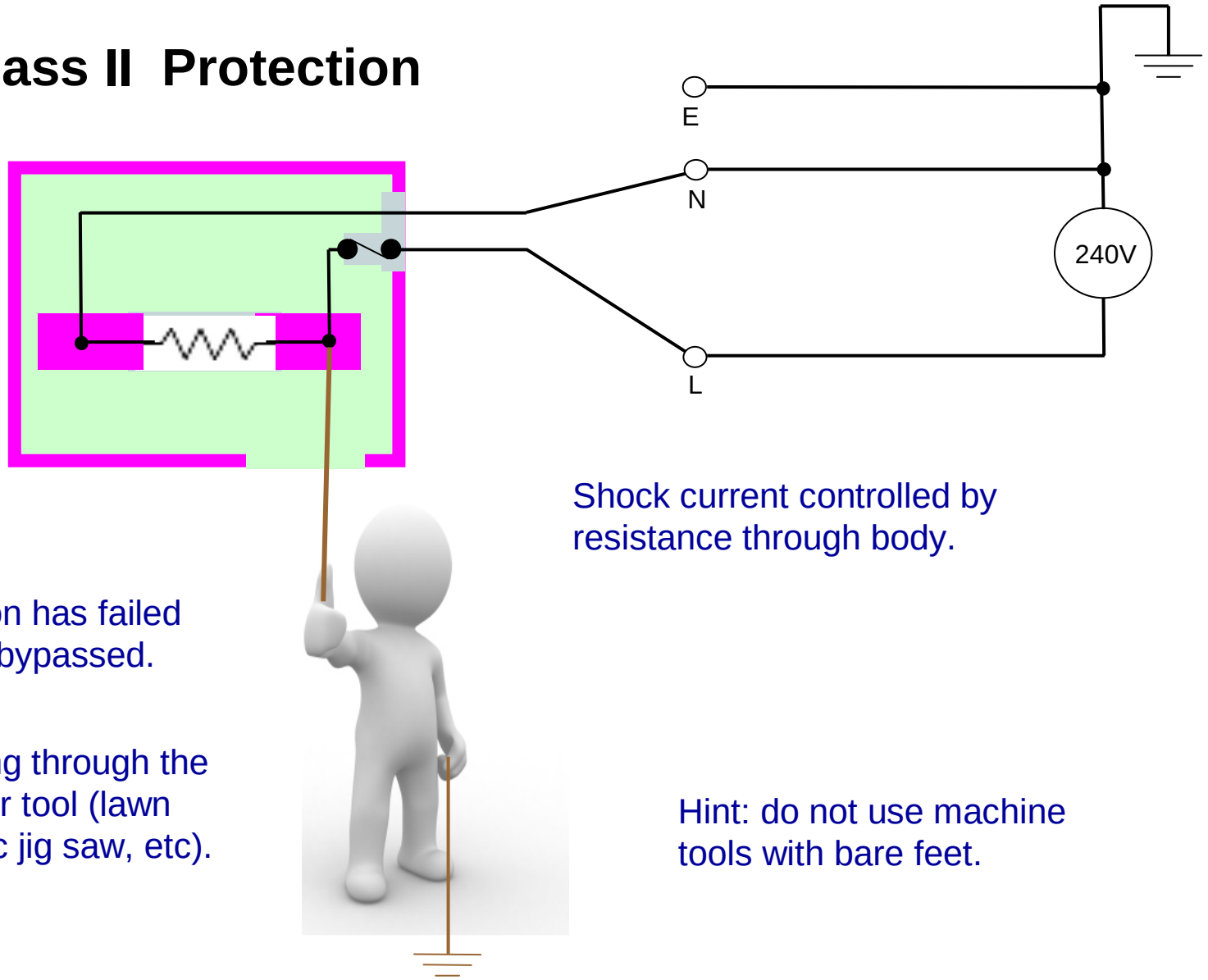


e.g. Hair Dryer

No protective earth
so no ELC

terminals inside
box (inaccessible)

Fault in Class II Protection



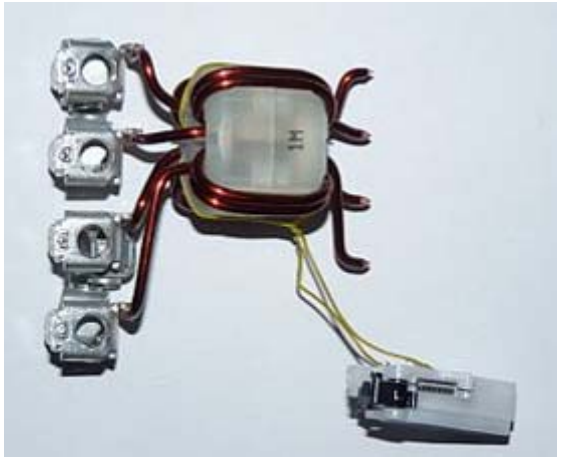
Shock current controlled by resistance through body.

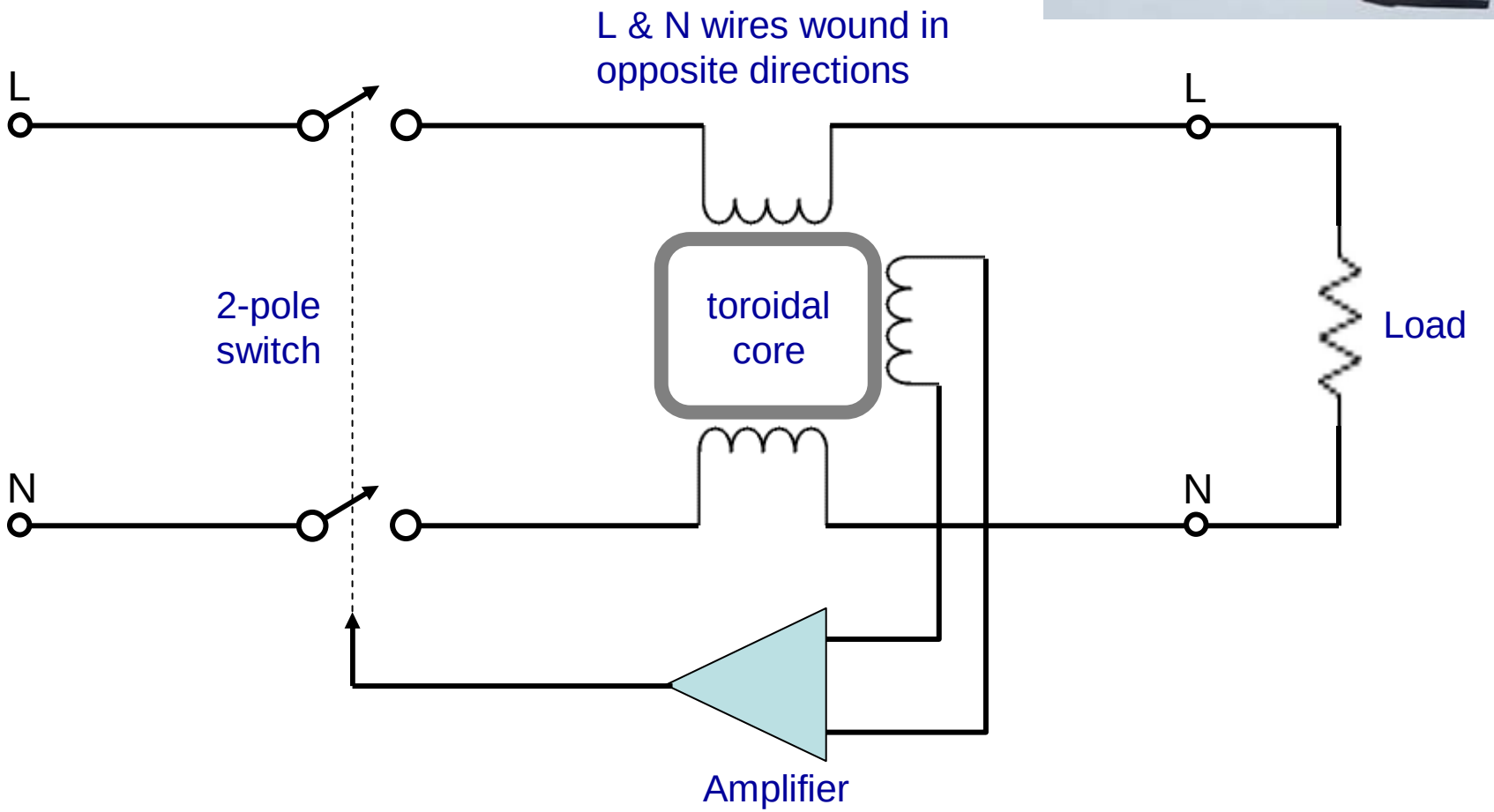
Either insulation has failed or it has been bypassed.

Example cutting through the lead to a power tool (lawn mower, electric jig saw, etc).

Hint: do not use machine tools with bare feet.

Residual Current Device: Principle



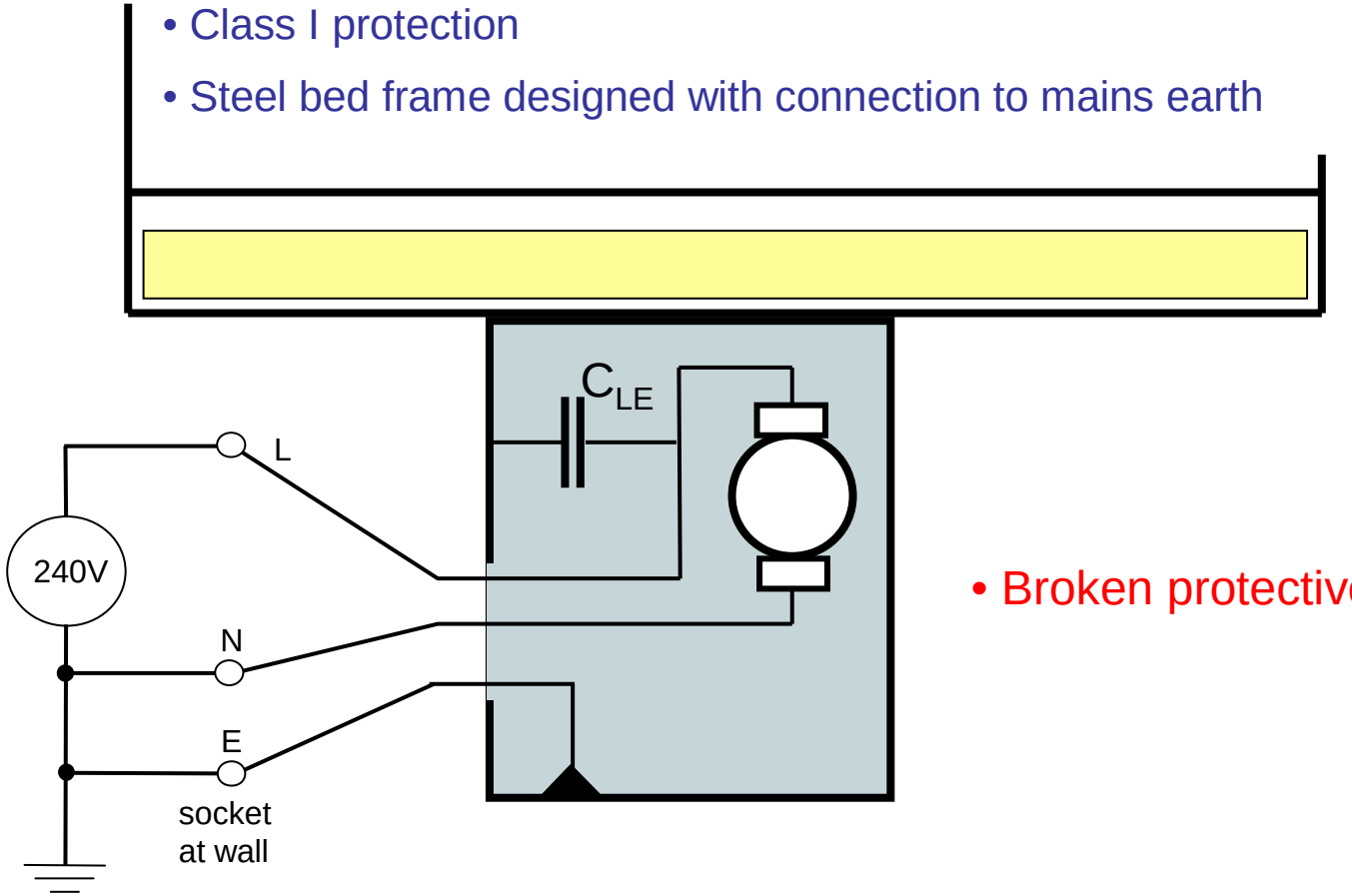


Microshock

The Faulty Bed & the Drug Infuser (1)

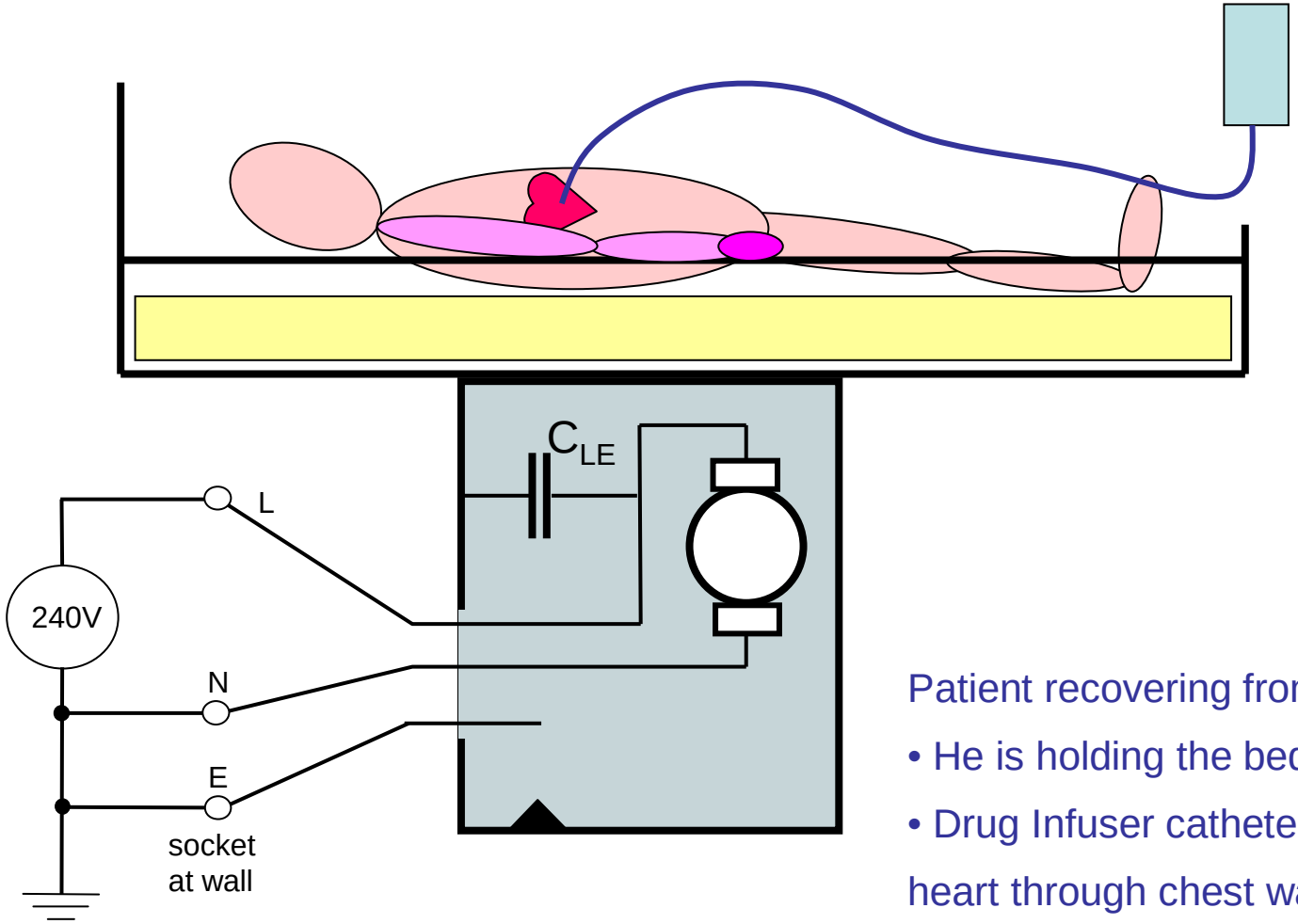
Bed in Intensive Care Unit

- Motorised to adjust height
- Mains filter with 4.7 nF capacitor
- Class I protection
- Steel bed frame designed with connection to mains earth



- Broken protective earth connection

The Faulty Bed & the Drug Infuser (2)



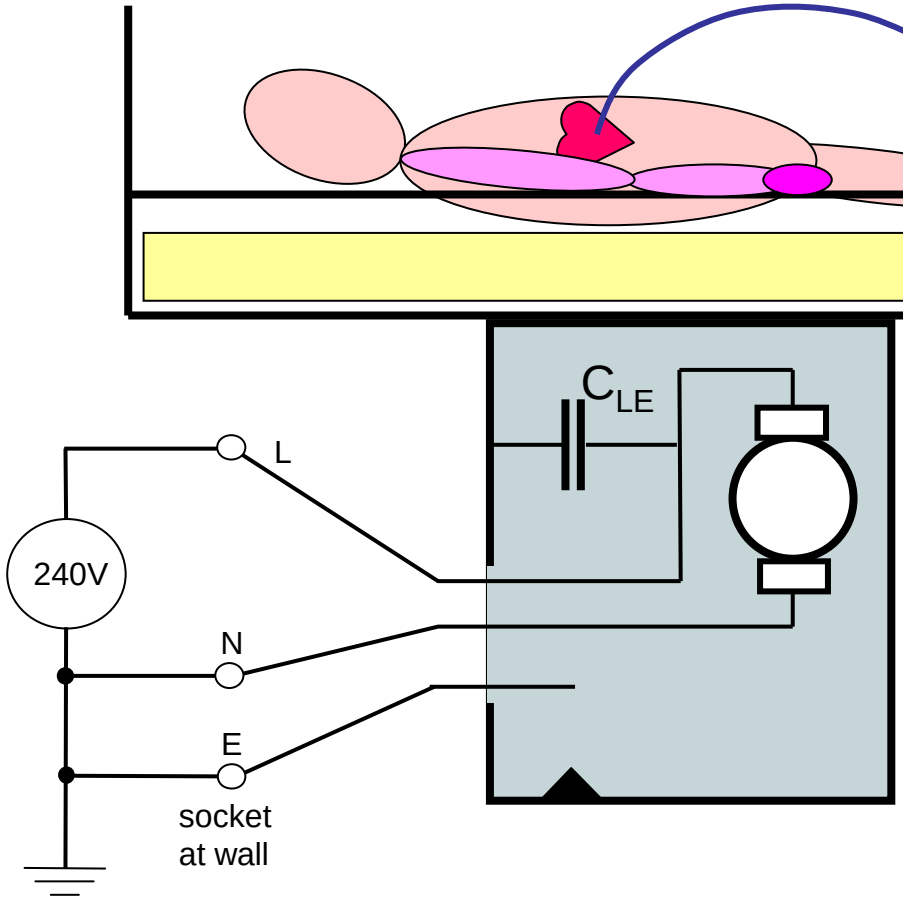
Patient recovering from cardiac surgery

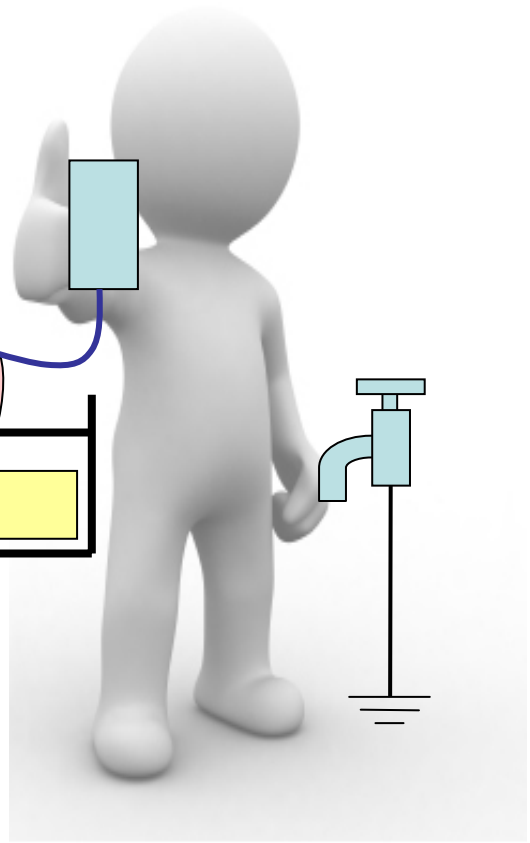
- He is holding the bed frame
- Drug Infuser catheter comes from heart through chest wall

The Faulty Bed & the Drug Infuser (3)

Cardiologist attends to patient

- Holding the Infuser so that he is touching the drug reservoir
- Touches earthed tap with other hand



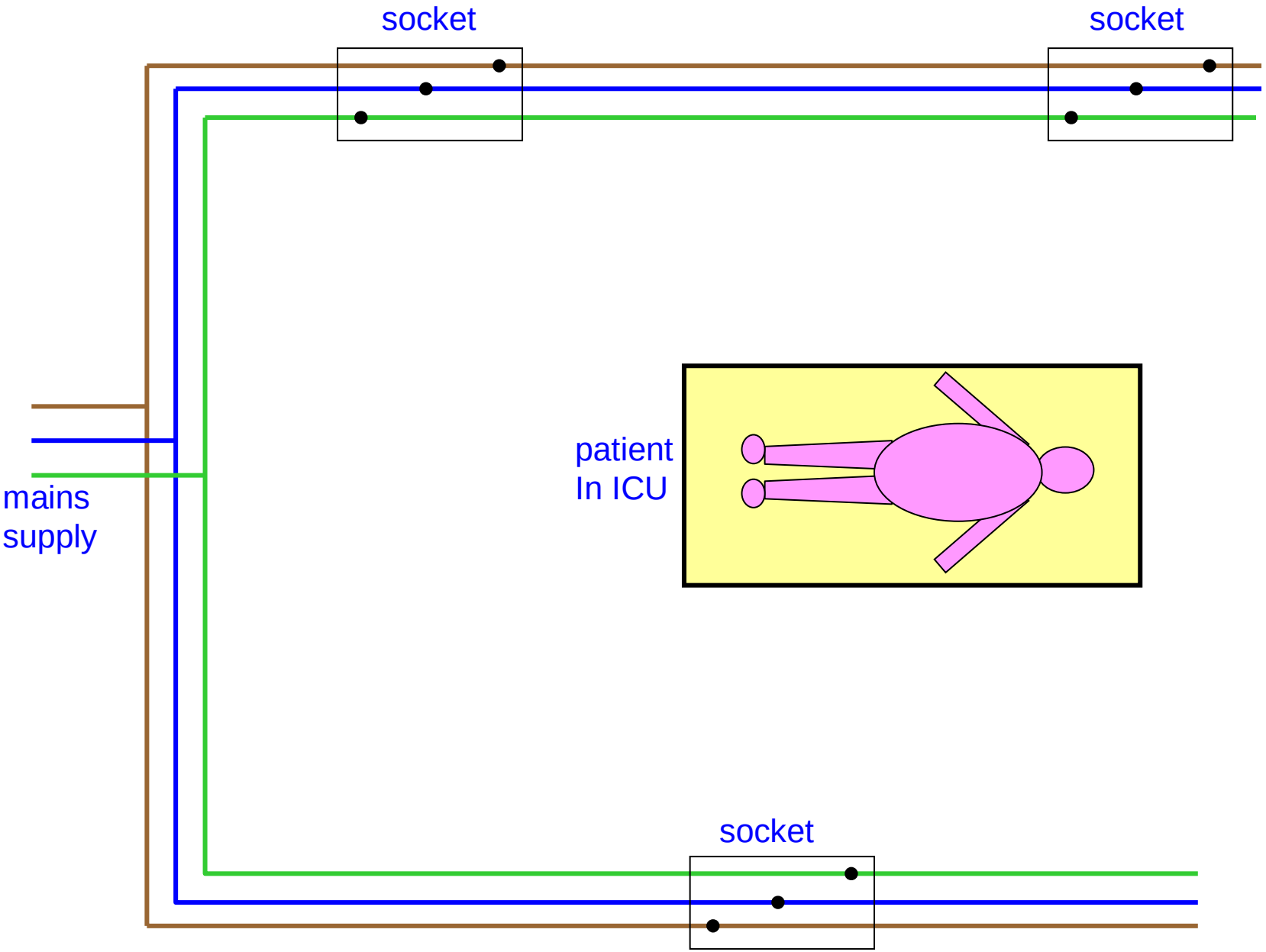


Result

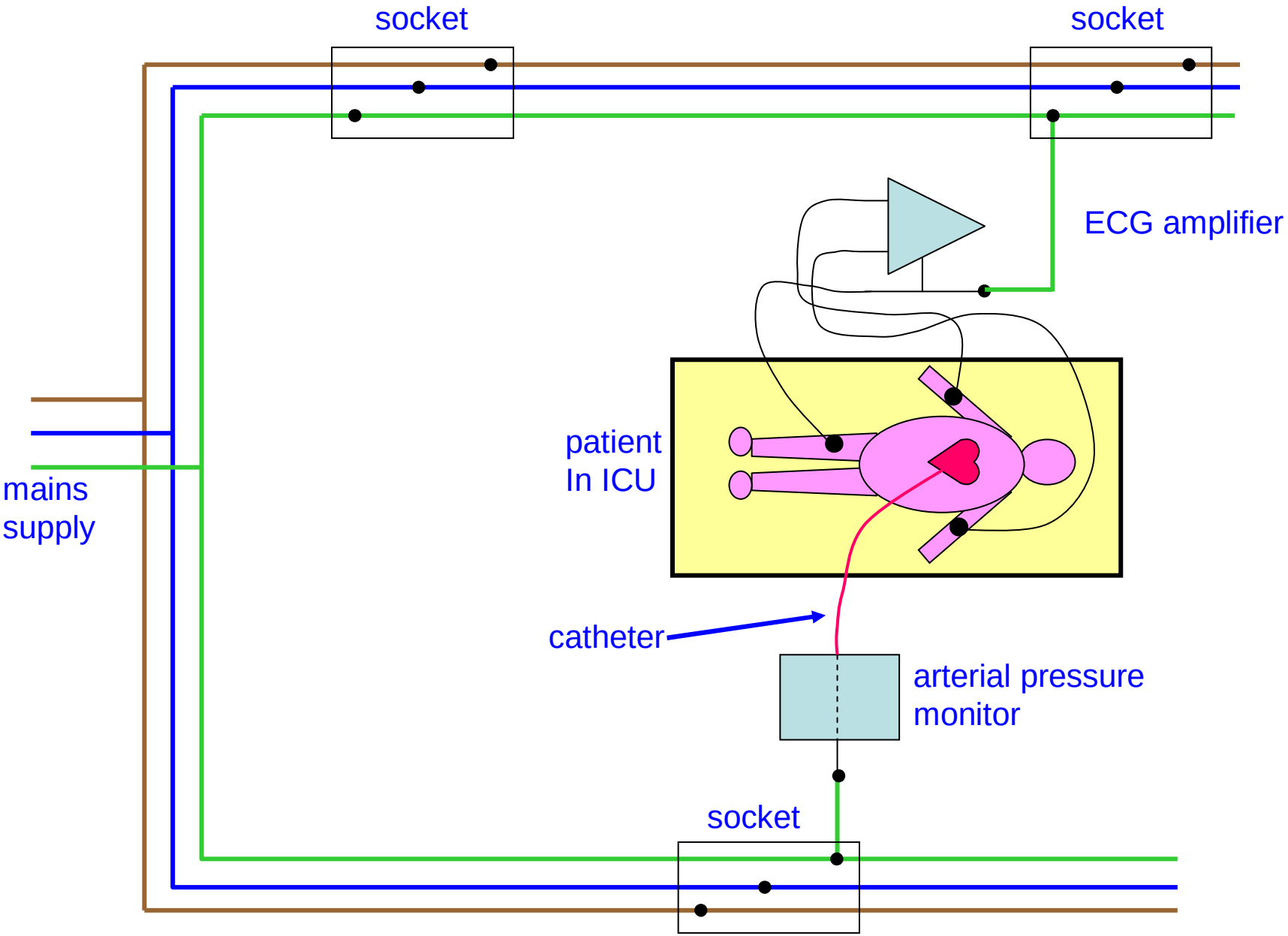
- **Cardiologist feels nothing, but**
- **Patient's heart goes into VF**

How many causes contribute to this accident?

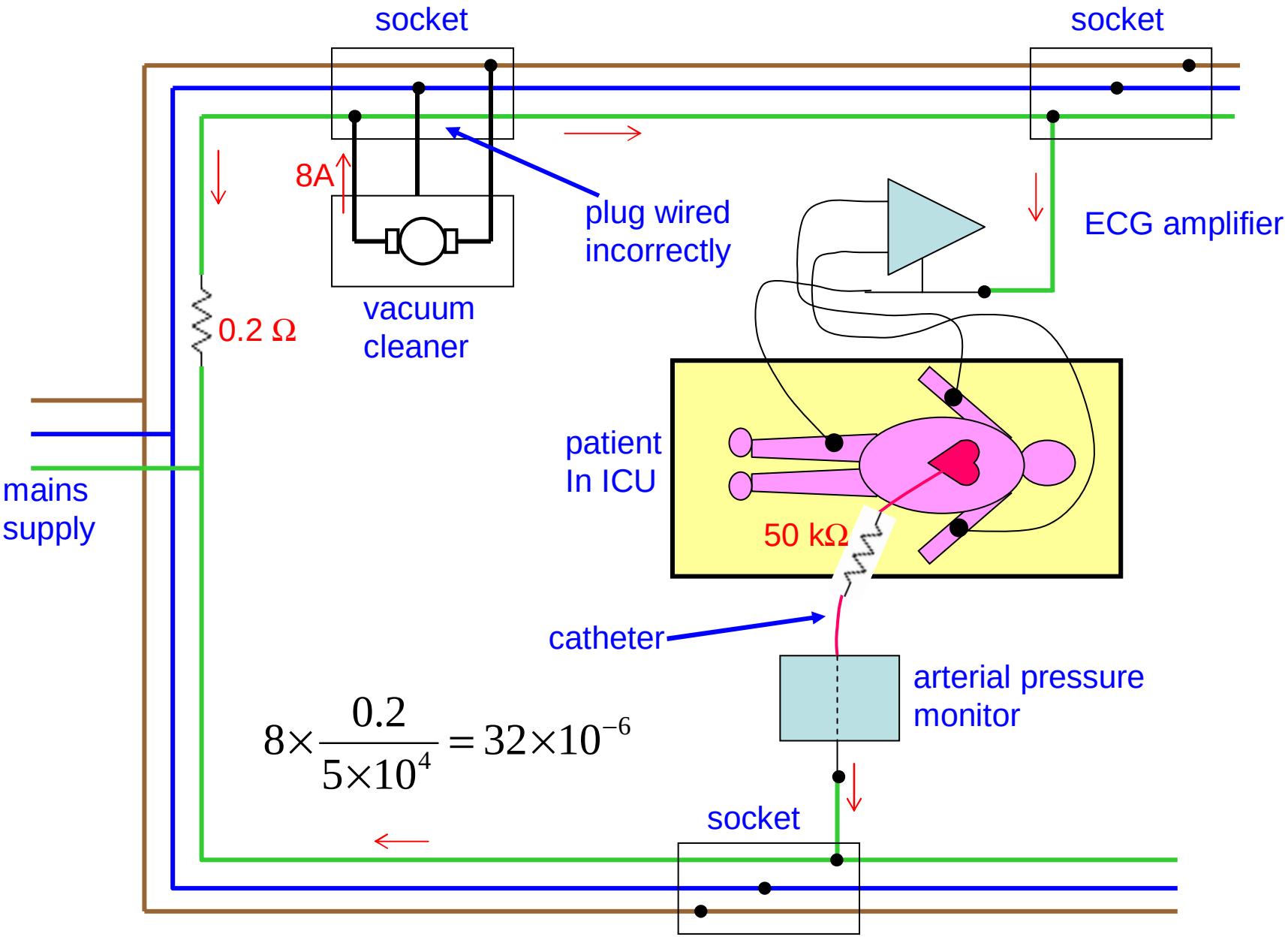
The Vacuum Cleaner Accident (1)



The Vacuum Cleaner Accident (2)

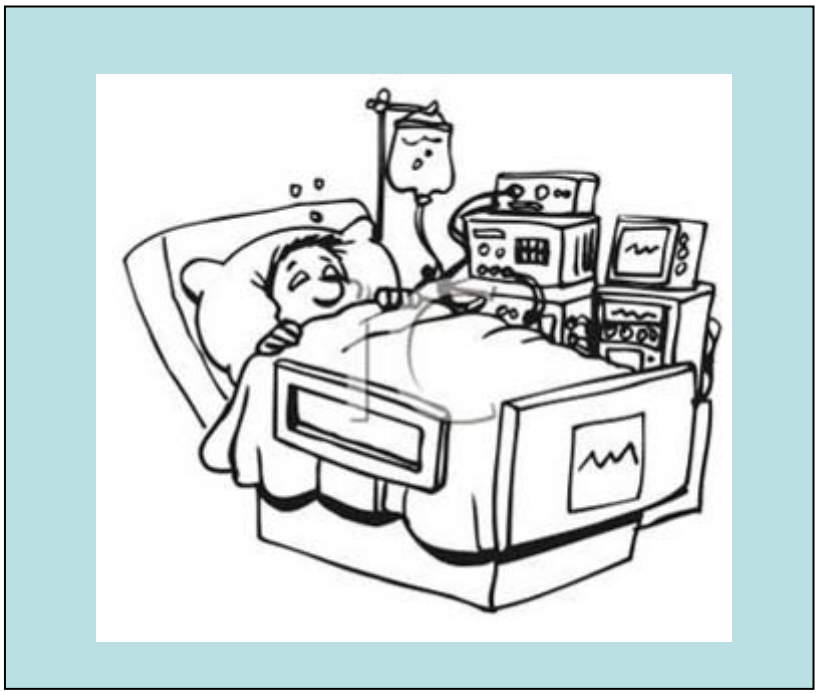


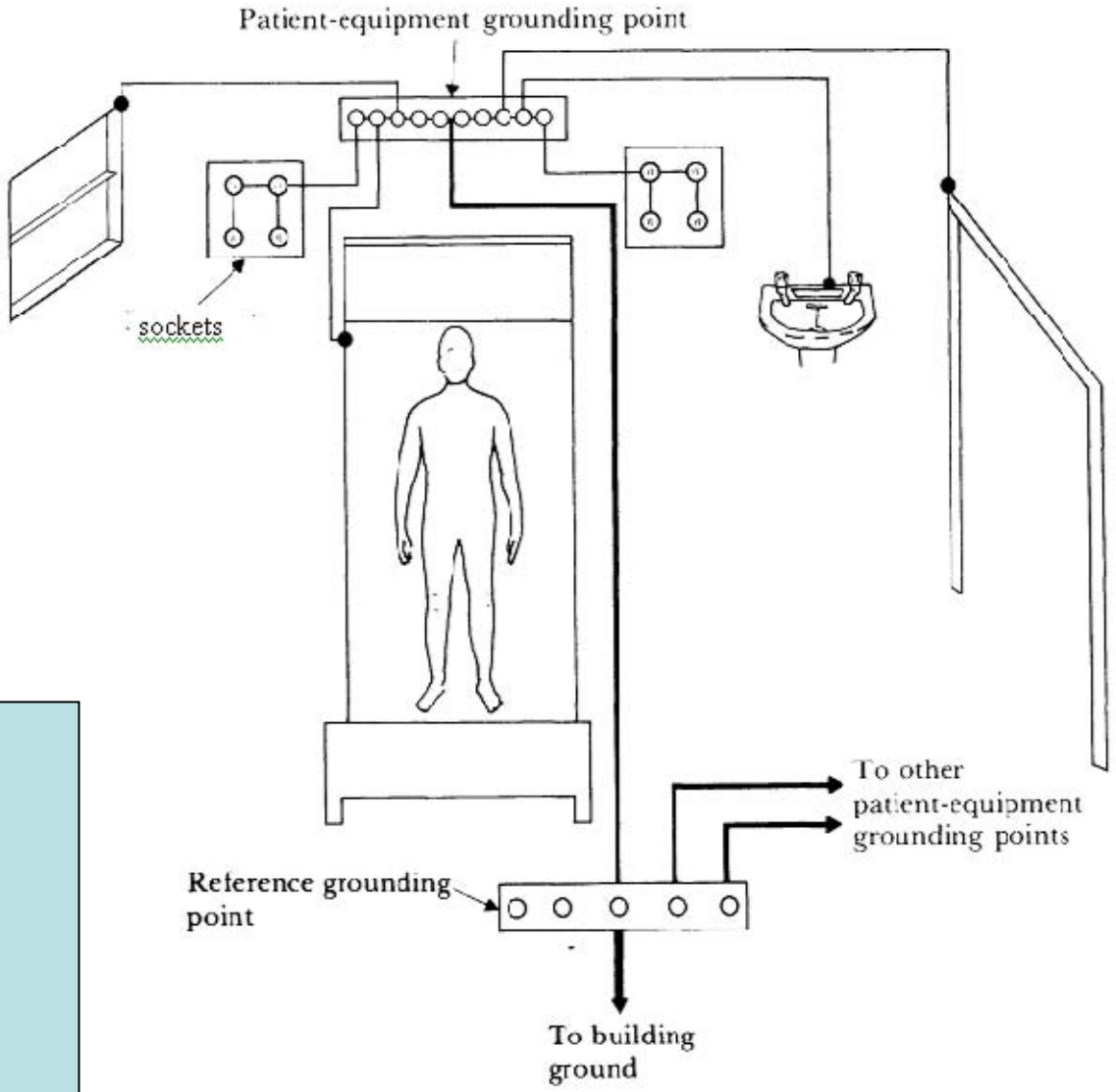
The Vacuum Cleaner Accident (3)



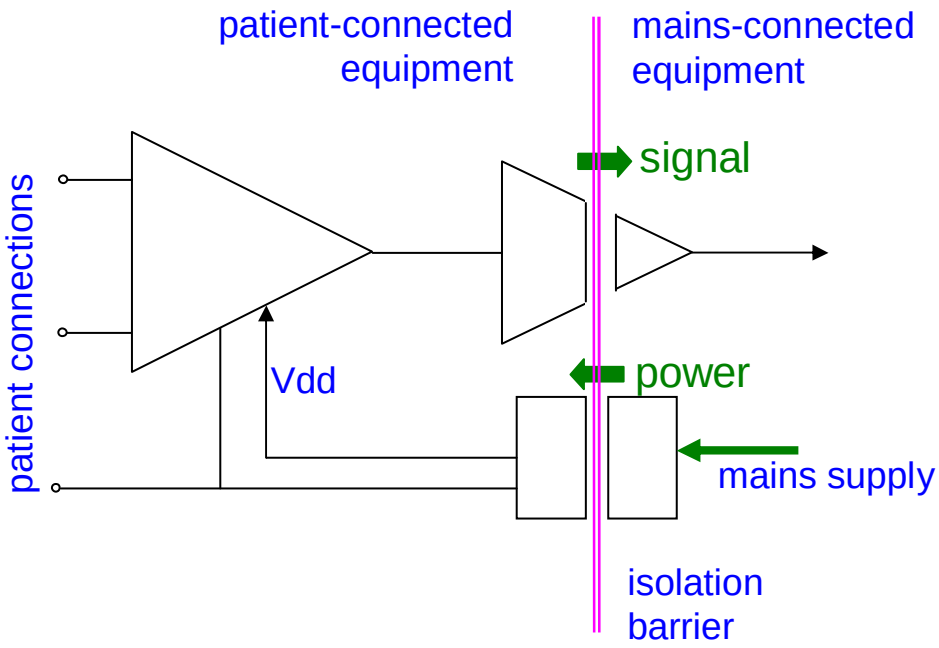
How many causes contribute to this accident?

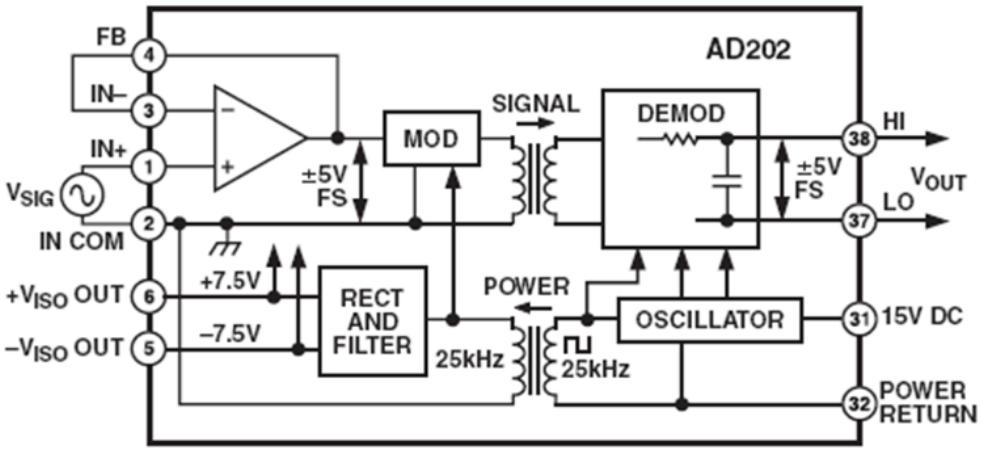
Proper Earthing





Isolation Barriers





AD202 Functional Block Diagram

Isolation methods:

- Transformers
- Capacitive coupling (at high frequencies)
- Opto-isolators
- Radio

Summary

You should now know enough about:

- the effects of electricity on the body,
- impedance calculations,
- Classes of protection,
- causes of macro-shock,
- causes of micro-shock,

to be able to understand the Regulations that Dr Fry will describe next week