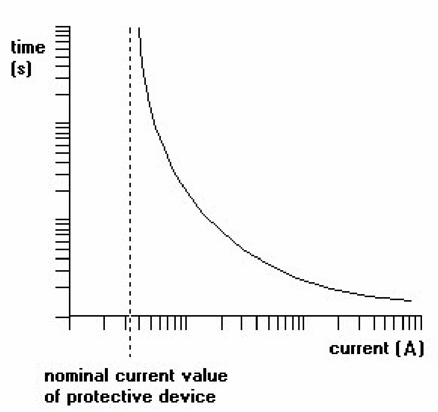
Electrical Safety

Protection

All electrical circuits and devices require protection against fault conditions, providing safety to personnel and preventing the device from severe damage. There are several forms of protection, each of which has its merits and particular uses.

Fuses – Semi-enclosed, cartridge



Fuses operate on the principle of melting when the heat absorbed exceeds its capacity.

Process is usually adiabatic – heat produced goes to heating the fuse wire only.

$\therefore I^2 R\, t$ = constant, or $I^2 t$ = constant.

where R is a constant corresponding to the resistance at the melting temperature.

Time – current characteristic seen corresponds to this expression.

Semi-enclosed fuses

Advantage

- cheap

Chief disadvantages are

- incorrect replacement easy
- subject to deterioration with time
- higher fusing factor (up to 2) than cartridge fuses (1.25 to 1.6)
- characteristic unreliable making discrimination difficult

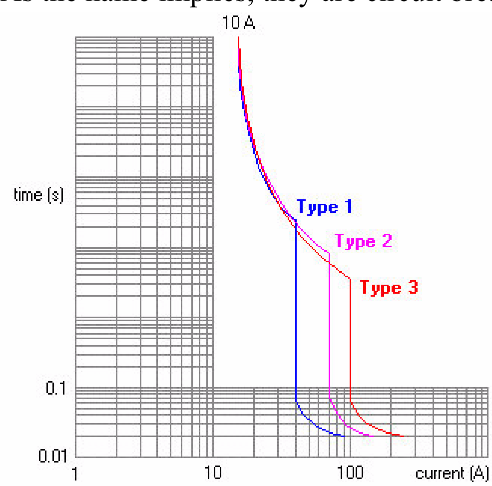
Cartridge fuses

Chief Advantages

- good discrimination
- predictable
- simple construction
- relatively low cost

Miniature Circuit Breakers (m.c.b.)

As the name implies, they are circuit breakers which are miniature in size.



They have two operating principles.

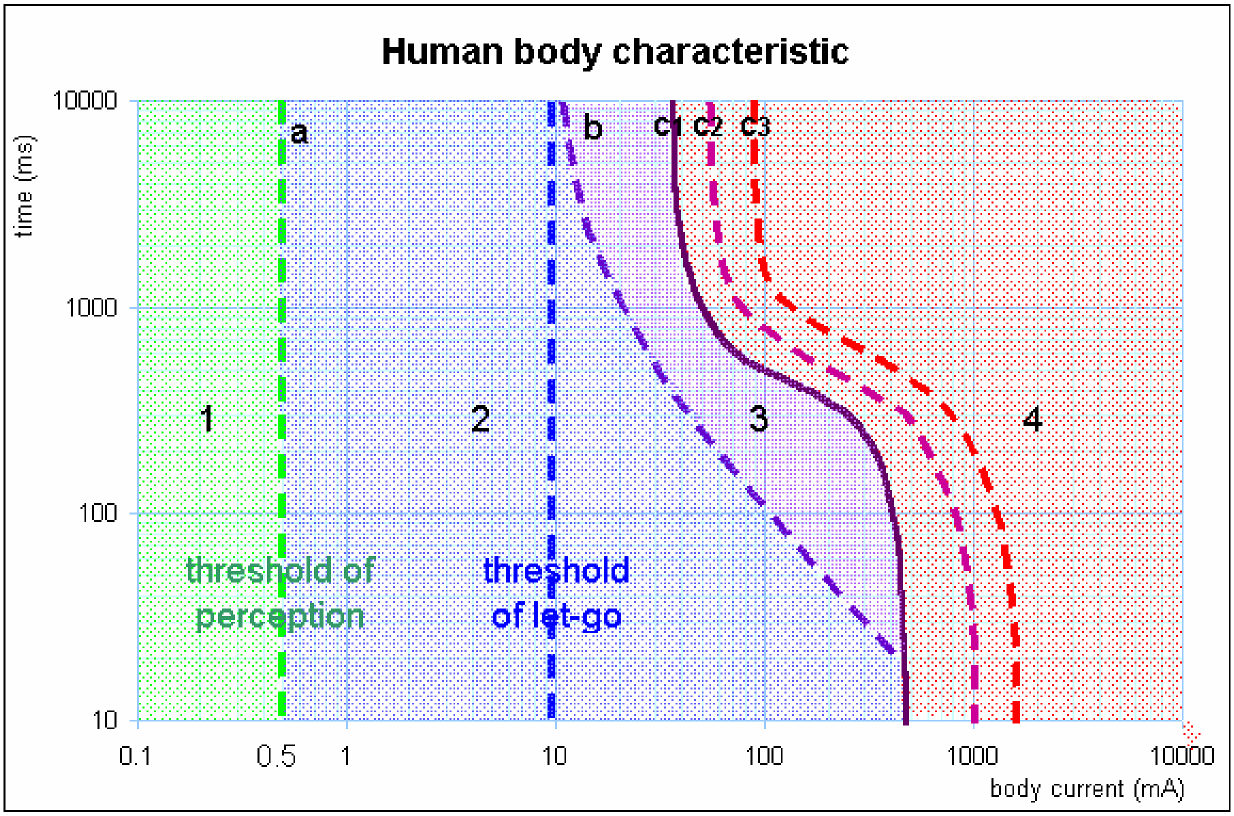
- bimetallic strip (thermal, I^2t characteristic)
- electromagnetic coil (near instantaneous operation for currents exceeding rated value)

Thermal characteristic is time dependant and is used for overload conditions.

Electromagnetic characteristic is almost instantaneous when current exceeds a set value and is used for Fault conditions.

Type 1 is general, and type 2 and type 3 are used when the circuit is inductive and the initial currents are much higher than steady state currents.

Electric Shock



Zones of effect of A.C.

The reaction of the human body to the passage of current varies with every human being.

The only way of quantifying the reaction is through statistical curves.

Figure relates the effect of the current I_{Beff} (mA) which flows through the body with the duration t(ms) of the current flow, for alternating currents of 50/60 Hz.

ZONES	**Physiological effects**
Zone 1	Usually no reaction
Zone 2	Usually no harmful physiological effect
Zone 3	Usually no organic damage to be expected. Likelihood of muscular contractions and difficulty in breathing. Reversible disturbances in the heart, including transient cardiac arrest without ventricular fibrillation. Increasing with current magnitude and time.
Zone 4	In addition to the effects of Zone 3, probability of ventricular fibrillation increasing up to about 5% (Curve C_2), up to about 50% (Curve C_3) and above 50% beyond Curve C_3. Increasing with magnitude and time, pathophysiological effects such as cardiac arrest, breathing arrest and heavy burns may occur.

The most damaging route of electricity is through the chest cavity or brain. Fatal ventricular fibrillation of the heart (stopping of rhythmic pumping action) can be initiated by a current flow of as little as several milliamperes.

Conventional limit of threshold of perception (no reaction, no painful shock and no loss of muscular control) 0.5 mA

[Practical value may be about 0.5 -1 mA for half the people & up to a maximum of about 1.5 mA]

Let-go current for majority of the persons (painful shock, possible loss of muscular control) 10 mA

[Practical value may be about 10-15 mA for half the people & up to a maximum of about 22 mA]

Normally considered safe voltage under dry conditions 50 V.

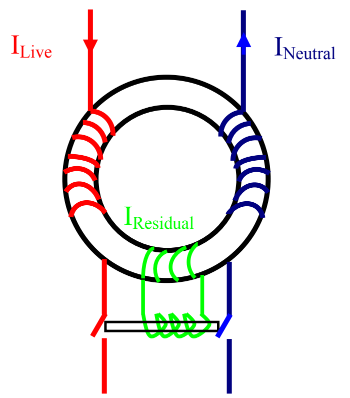
Value for the total body impedance = 1000 to 2000 Ω for a current path hand to hand or hand to foot for large contact areas (50 cm^2 to 100 cm^2) and dry conditions at 230 V, 50 Hz.

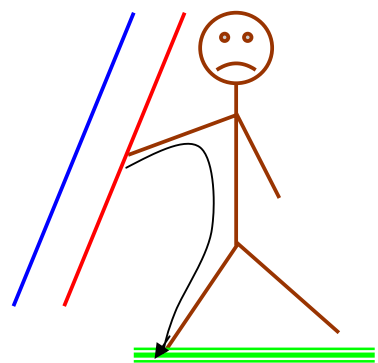
The surface of the skin can be a preferential path for the current when it is wet, strongly decreasing the resistance value.

Residual Current Circuit Breaker

Residual current circuit breaker operates based on a difference in the live wire and the neutral wire current. Such differences normally occur during faults where currents pass through unintended paths

Ex: Frames of equipment, human body





$I_{Residual} \propto I_{Live} - I_{Neutral}$

Earthing

Earthing or Grounding is done to connect an equipment frame or circuit node to the general mass of the earth. That is to make the potential of that node fixed at the reference potential of zero or close to it.

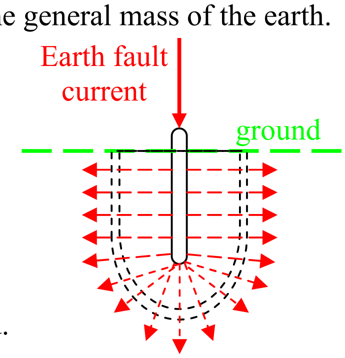
This is usually done in the domestic or office environment by connecting a wire to an earthing electrode buried in the earth or ground. The common methods of earthing are to use (a) a galvanised iron pipe (GI pipe) of diameter about 50 mm and length about 2 m, (b) a copper rod, or (c) a copper plate. By this means the circuit is in contact with the general mass of the earth. However, the contact is not perfect and an effective resistance exists between the wire and the general mass of the earth.

Earth Electrode Resistance

This resistance is usually referred to as the earth electrode resistance. As in the case of any other resistance, the earth electrode resistance also depends on the resistivity (ρ) of the soil or earth.

For a pipe or rod, the following calculation gives an idea of how the electrode resistance may be determined.

Consider a pipe buried to a depth of h below the surface of the ground.

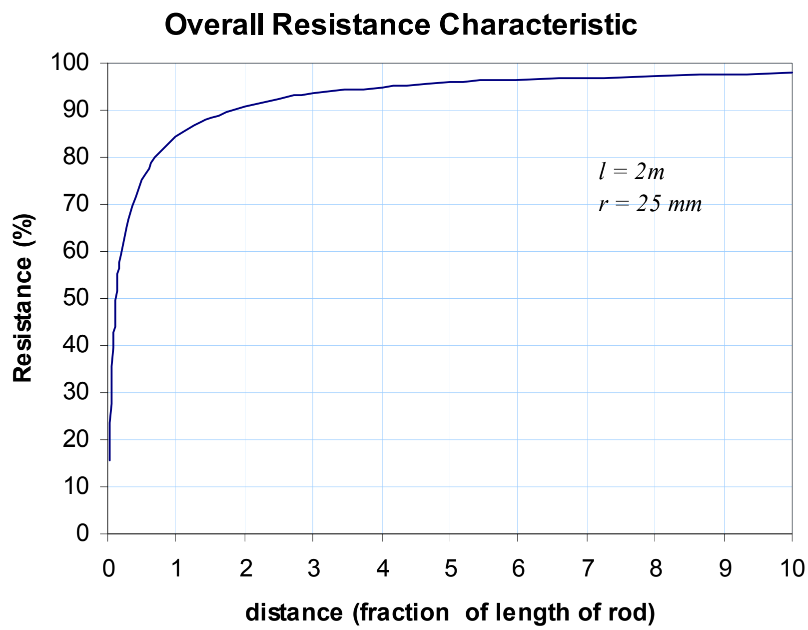


Consider the currents going out from it in a shape of a cylinder and a hemi-sphere at a radius of ***x*** as shown.

Consider an elemental cylinder of thickness ***dx*** . The resistance ***dR*** of this can be calculated as follows.

$$\text{using } R = \frac{\rho\, l}{A}, \quad dR = \frac{\rho.dx}{2\pi\, x^2 + 2\pi\, x.l} = \frac{\rho.dx}{2\pi\ x(x+l)} = \frac{\rho}{2\pi\, l}\left[\frac{1}{x} - \frac{1}{x+l}\right].dx$$

$$\int_0^R dR = \int_r^x \frac{\rho}{2\pi\, l}\left[\frac{1}{x} - \frac{1}{x+l}\right]dx \quad \Rightarrow \quad R = \frac{\rho}{2\pi\ l}\left[\ln\left(\frac{x}{r}\right) - \ln\left(\frac{x+l}{r+l}\right)\right]$$



as ***x*** tends to infinity, that is as a large mass of the earth is taken into consideration, the limiting value of the electrode resistance would be

$$R = \frac{\rho}{2\pi\, l}\left[\frac{r+l}{r}\right]$$

It is seen that about 90% of the value is reached within about twice the length of the rod or pipe. Thus the resistance area of the electrode can be taken for practical purposes to be an area around the rod with a radius of approximately twice the depth of the electrode.