NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

RESTAURANT ILLUMINATION

GRADUATION PROJECT
EE400

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I dedicate my work and success to my father **Ali Ibrahem**, my mother and my brothers Specially I wish to express my deepest appreciation to my brother **Eng:khaled smadi** who provided me the encouragement enough to finish my studies

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ABSTRACT

This project is prepared as a thesis for graduating in 2008-2009 education year, Near East University Engineering Faculty, Electric and Electronic Engineering department.

The interior electrical installation of a preparation restaurant is going to be designed in this project with a brief description of the basic components of installation along with the illumination calculations.

The aim is to meet the standard installation requirements and take into consideration the power consumptions along with the decorative side of installation.

INTRODUCTION

Lighting includes both artificial light sources such as lamps and natural illumination of interiors from daylight. Lighting represents a major component of energy consumption, accounting for a significant part of all energy consumed worldwide. Artificial lighting is provided today by electric lights, but previously by gas lighting, candles or oil lamps. Proper lighting can enhance task performance or aesthetics, while there can be energy wastage and adverse health effects of lighting. Indoor lighting is a form of fixture or furnishing, and a key part of interior design.

The Thesis consist of the introduction, four chapters and aconclusion.

Chapter 1 is concerned in cables, explaining the different insulation materials used on cables and current carrying capacity of the conductors showing how heat plays a big role in the capacity of the current carried, then cable rating calculations is taken into concideration by giving some examples to clearify the subject, and finaly voltage drop of cables is mentioned also showing by examples how it can be calculated.

Chapter 2 is splitted into two parts, the first part speaks about the basic requirments for circuit and showing by figures how does typical arrangement for feeding final circuits in a domestic installation look like and an arrangement for main and final circuits in a large installation as well, the second part is concerned in the distribution board and its components and specially the circuit breaker which is given the biggest amount of explanation showing its parts and kinds.

Chapter 3 studies sockets and lighting circuits explaining ring and radial circuits of sockets and when they are used and showing both theoretical and practical circuits of lighting.

Chapter 4 is devoted to the illumination and voltage-current calculations taking three different areas of the plan as examples for illumination calculations to figure out how many lamps should be used in each area depending on its kind and other factors as well, and finally showing the list of prices for the components used in the project according to the EMO's list of prices of the year 2008 and lighting glossary

CHAPTER ONE

LIGHT AND CABLES

1.1. Light

What is light: Light is a form of radiant energy that travels in waves made up of vibrating electric and magnetic fields? These waves have both a frequency and a length, the values of which distinguish light from other forms of energy on the electromagnetic spectrum. Visible light, as can be seen on the electromagnetic spectrum, represents a narrow band between ultraviolet light (UV) and infrared energy (heat). These light waves are capable of exciting the eye's retina, which results in a visual sensation called sight. Therefore, seeing requires a functioning eye and visible light.

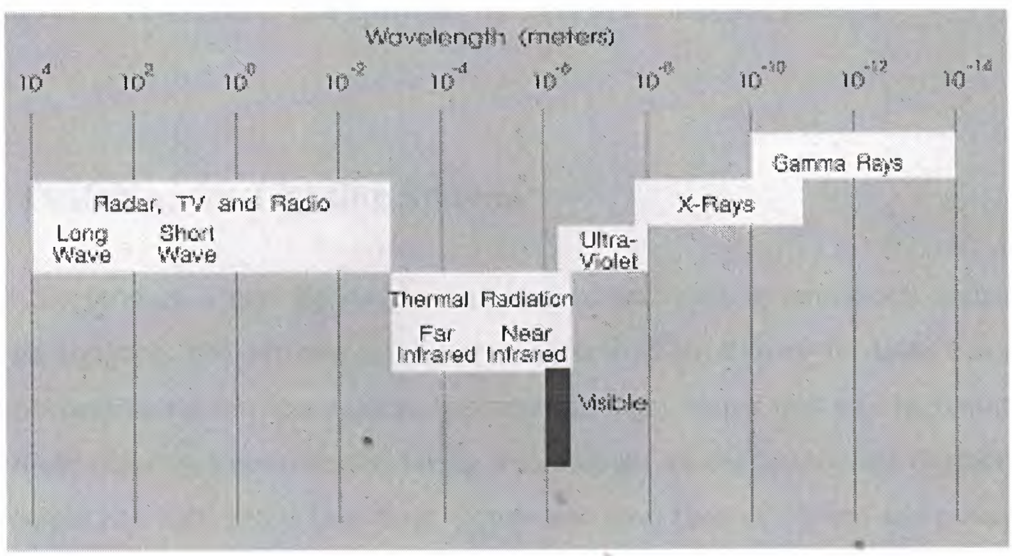

Figure 1.1: Electromagnetic field spectrums

1.2. Lighting Systems:

Light can be produced by nature or by humans. "Artificial" light is typically produced by lighting systems that transform electrical energy into light. Nearly all lighting systems do so either by passing an electrical current through an element that heats until it glows, or through gases until they become excited and produce light energy. Incandescent light sources are an example of the first method, called incandescence. Current is passed through a filament, which heats until it glows. Because this method is considered wasteful (most of the energy entering the lamp leaves it as heat instead of visible light, other light sources were pioneered that rely on the gaseous discharge method, including fluorescent, high-intensity discharge (HID) and low-pressure sodium light sources. typical lighting system is comprised of one or more of these light sources, called the lamps. Fluorescent, HID and low-pressure sodium lamps operate with ballast, a device that starts the lamp and regulates its operation. Lamps and ballasts in turn are part of the luminaries, or light fixture, which houses the system and includes other components that distribute the light in a controlled pattern.

1.3. Designing the Lighting System:

To produce a new lighting system in a construction or renovation scenario, it must be designed. The designer must determine desired light levels for tasks that are to be performed in a given space, then determine the light output that will be required to meet those objectives consistently, taking into account all the factors that degrade both light output and light levels over time. Equipment must then be chosen and placed in a layout to produce the desired light distribution. The designer must also consider a range of quality factors in his or her design choices and equipment selection, including color, minimizing glare, safety and if required, aesthetics.

1.4. Cable Insulation Materials

1.4.1. Rubber

For many years wiring cables were insulated with vulcanised natural rubber (VIR). Much cable of this type is still in service, although it is many years since it was last manufactured. Since the insulation is organic, it is subject to the normal ageing process, becoming hard and brittle. In this condition it will continue to give satisfactory service unless it is disturbed, when the rubber cracks and loses its insulating properties. It is advisable that wiring of this type which is still in service should be replaced by a more modern cable. Synthetic rubber compounds are used widely for insulation and sheathing of cables for flexible and for heavy duty applications. Many variations are possible, with conductor temperature ratings from 60°C to 180°C, as well as resistance to oil, ozone and ultra-violet radiation depending on the formulation.

1.4.2. Paper

Dry paper is an excellent insulator but loses its insulating properties if it becomes wet. Dry paper is hygroscopic, that is, it absorbs moisture from the air. It must be sealed to ensure that there is no contact with the air. Because of this, paper insulated cables are sheathed with impervious materials, lead being the most common. PILC (paper insulated lead covered) is traditionally used for heavy power work. The paper insulation is impregnated with oil or non-draining compound to improve its long-term performance. Cables of this kind need special jointing methods to ensure that the insulation remains sealed. This difficulty, as well as the weight of the cable, has led to the widespread use of p.v.c. and XLPE (thermosetting) insulated cables in place of paper insulated types.

1.4.3. P.V.C.

Polyvinyl chloride (p.v.c.) is now the most usual low voltage cable insulation. It is clean to handle and is reasonably resistant to oils and other chemicals. When p.v.c. burns, it emits dense smoke and corrosive hydrogen chloride gas. The physical characteristics of the material change with temperature: when cold it becomes hard and difficult to strip, and so BS 7671 specifies that it should not be worked at temperatures below 5°C. However a special p.v.c. is available which remains flexible at temperatures down to -20°C.

At high temperatures the material becomes soft so that conductors which are pressing on the insulation (e.g. at bends) will 'migrate' through it, sometimes moving to the edge of the insulation. Because of this property the temperature of general purpose P.V.C. must not be allowed to exceed 70°C, although versions which will operate safely at temperatures up to 85°C are also available. If p.v.c. is exposed to sunlight it may be degraded by ultra-violet radiation. If it is in contact with absorbent materials, the plasticizers may be 'leached out' making the p.v.c. hard and brittle.

1.4.4. LSF (Low smoke and fume)

Materials which have reduced smoke and corrosive gas emissions in fire compared with p.v.c. have been available for some years. They are normally used as sheathing compounds over XLPE or LSF insulation, and can give considerable safety advantages in situations where numbers of people may have to be evacuated in the event of fire.

1.4.5. Thermosetting (XLPE)

Gross-linked polyethylene (XLPE) is a thermosetting compound which has better electrical properties than p.v.c. and is therefore used for medium- and high-voltage applications. It has more resistance to deformation at higher temperatures than p.v.c., which it is gradually replacing. It is also replacing PILC in some applications. Thermosetting insulation may be used safely with conductor temperatures up to 90°C thus increasing the useful current rating, especially when ambient temperature is high. A LSF (low smoke and fume) type of thermosetting cable is available.

1.4.6. Mineral

Provided that it is kept dry, a mineral insulation such as magnesium oxide is an excellent insulator. Since it is hygroscopic (it absorbs moisture from the air) this insulation is kept sealed within a copper sheath. The resulting cable is totally fireproof and will operate at temperatures of up to 250°C. It is also entirely inorganic and thus non-ageing. These cables have small diameters compared with alternatives, great mechanical strength, are waterproof, resistant to radiation and electromagnetic pulses, are pliable and corrosion resistant. In cases where the copper sheath may corrode, the cable is used with an overall LSF covering, which reduces the temperature at which the cable may be allowed to operate. Since it is necessary to prevent the ingress of moisture, special seals are used to terminate cables.

1.5. Current Carrying Capacity of Conductors

All cables have electrical resistance, so there must be an energy loss when they carry current. This loss appears as heat and the temperature of the cable rises. As it does so, the heat it loses to its surroundings by conduction, convection and radiation also increases. The rate of heat loss is a function of the difference in temperature between the conductor and the surroundings, so as the conductor temperature rises, so does its rate of beat loss. A cable carrying a steady current, which produces a fixed heating effect, will get hotter until it reaches the balance temperature where heat input is equal to heat loss. The final temperature achieved by the cable will thus depend on the current carried, how easily heat is dissipated from the cable and the temperature of the cable surroundings.

PVC. Is probably the most usual form of insulation, and is very susceptible to damage by high temperatures. It is very important that p.v.c. insulation should not be allowed normally to exceed 70°C, so the current ratings of cables are designed to ensure that this will not happen. Some special types of p.v.c. may be used up to 85°C. A conductor temperature as high as 160°C is permissible under very short time fault conditions, on the assumption that when the fault is cleared the p.v.c. insulation will dissipate the heat without itself reaching a dangerous temperature.

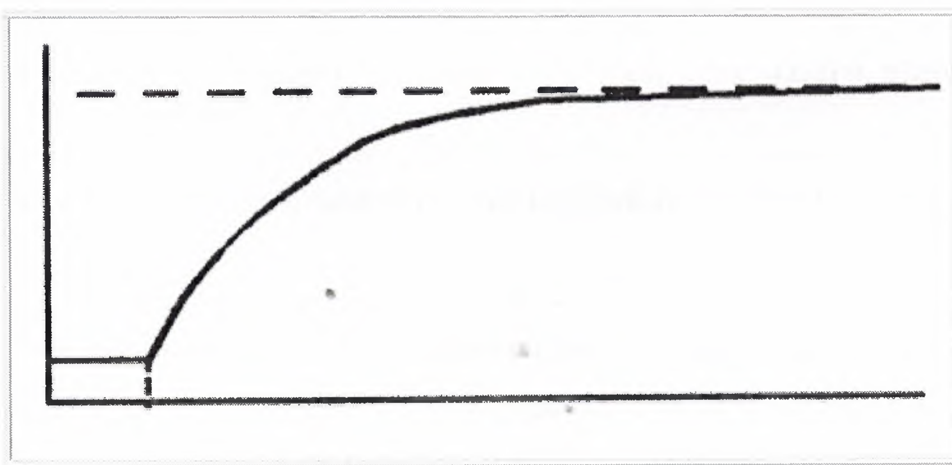

Fig1.2: Heat balance graph for a cable.

A different set of cable ratings will become necessary if the ability of a cable to shed its beat changes.

For example, if a mineral insulated cable has an overall sheath of LSF or p.v.c., the copper sheath temperature must not exceed 70°C, whilst if the copper sheath is bare and cannot be touched and is not in contact with materials which are combustible its temperature can be allowed to reach 150°C. Thus, a $1mm^2$ light duty twin mineral insulated cable has a current rating of 18.5 A when it has an LSF or p.v.c. sheath, or 22 A if bare and not exposed to touch. It should be noticed that the cable volt drop will be higher if more current is carried.

1.6. Cable Rating Calculation

There is an increasing move away from 70°C P.V.C. insulation to materials which are more environmentally friendly, for example 90°C XLPE. The ratings of fuse gear, switches, accessories etc. are generally based upon the equipment being connected to conductors intended to be operated at a temperature not exceeding 70°C in normal service.

In view of the above it is recommended that the practice of designs based upon conductor temperatures of 70°C be regarded as the norm. In accordance with clause 512-02-01 of the Wiring Regulations the equipment manufacturer should be consulted to ascertain the reduction of nominal current rating of the equipment if conductor temperatures exceeding 70°C are used. In addition an overriding factor is often voltage drop consideration.

The Regulations indicate the following symbols for use when selecting cables:

Iz	is the current carrying capacity of the cable in the situation where it is installed
It	is the tabulated current for a single circuit at an ambient temperature of 30°C
Ib	is the design current, the actual current to be carried by the cable
In	is the rating of the protecting fuse or circuit breaker
I2	is the operating current for the fuse or circuit breaker (the current at which the fuse blows or the circuit breaker opens)
Ca	is the correction factor for ambient temperature
Cg	is the correction factor for grouping

Ci	is the correction factor for thermal insulation.

The correction factor for protection by a semi-enclosed (rewirable) fuse is not given a symbol but has a fixed value of 0.725.

Under all circumstances, the cable current carrying capacity must be equal to or greater than the circuit design current and the rating of the fuse or circuit breaker must be at least as big as the circuit design current. These requirements are common sense, because otherwise the cable would be overloaded or the fuse would blow when the load is switched an.

To ensure correct protection from overload, it is important that the protective device operating current (I2) is not bigger than 1.45 times the current carrying capacity of the cable (Iz). Additionally, the rating of the fuse or circuit breaker (In) must not be greater than the cable current carrying capacity (Iz) It is important to appreciate that the operating current of a protective device is always larger than its rated value. In the case of a back-up fuse, which is not intended to provide overload protection, neither of these requirements applies.

To select a cable for a particular application, take the following steps:

1-Calculate the expected (design) current in the circuit (Ib)

2-Choose the type and rating of protective device (fuse or circuit breaker) to be used

3-Divide the protective device rated current by the ambient temperature correction factor (Ca) if ambient temperature differs from 30°C

4-Further divide by the grouping correction factor (Cg)

5-Divide again by the thermal insulation correction factor (CI)

6-Divide by the semi-enclosed fuse factor of 0.725 where applicable

7-The result is the rated current of the cable required, which must be chosen from the appropriate tables (1.1 to 1.4).

Observe that one should divide by the correction factors, whilst in the previous subsection we were multiplying them. The difference is that here we start with the design current of the circuit and adjust it to take account of factors which will derate the cable. Thus, the current carrying capacity of the cable will be equal to or greater than the design current.

(Tables 1.1 to 1.4) give current ratings and volt drops for some of the more commonly used cables and sizes. The Tables assume that the conductors and the insulation are operating at their maximum rated temperatures.

For example if an immersion heater rated at 240 V, 3 kW is to be installed using twin with protective conductor p.v.c. insulated and sheathed cable. The circuit will be fed from a 15 A miniature circuit breaker type 2, and will be run for much of its 14 m length in a roof space which is thermally insulated with glass fiber. The roof space temperature is expected to rise to 50°C in summer, and where it leaves the consumer unit and passes through a 50 mm insulation-filled cavity, the cable will be bunched with seven others. To calculate the cross-sectional area of the required cable,

First calculate the design current Ib

$$IB = \frac{P}{U} = \frac{3000\ A}{240} = 12.5\ A$$

The ambient temperature correction factor is found to be 0.71. The group correction factor is found as 0.52. (The circuit in question is bunched with seven others, making eight in all).

The thermal insulation correction factor is already taken into account in the current rating table and need not be further considered. This is because we can assume that the cable in the roof space is in contact with the glass fibre but not enclosed by it. What we must consider is the point where the bunched cables pass through the insulated cavity, we have a factor of 0.89.

The correction factors must now be considered to see if more than one of them applies to the same part of the cable. The only place where this happens is in the insulated cavity behind the consumer unit. Factors of 0.52 (Cg) and 0.89 (CI) apply. The combined value of these (0.463), which is lower than the ambient temperature correction factor of 0.71, and will thus, be the figure to be applied. Hence the required current rating is calculated:-

$$Iz = \frac{in}{Cg \times Ci} = \frac{15\ A}{0.52 \times 0.89} = 32.4\ A$$

Table 1.1 - Current ratings and volt drops for unsheathed single core p.v.c. insulated cables

Cross sectional area	In conduit in thermal insulation	In conduit in thermal insulation	In conduit on wall	In conduit on wall	Clipped direct	Clipped direct	Volt drop	Volt drop
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(mV/A/m)	(mV/A/m)
-	2 cables	3 or 4 cables	2 cables	3 or 4 cables	2 cables	3 or 4 cables	2 cables	3 or 4 cables
1.0	11.0	10.5	13.5	12.0	15.5	14.0	44.0	38.0
1.5	14.5	13.5	17.5	15.5	20.0	18.0	29.0	25.0
2.5	19.5	18.0	24.0	21.0	27.0	25.0	18..0	15.0
4.0	26.0	24.0	32.0	28.0	37.0	33.0	11.0	9.5
6.0	34.0	31.0	41.0	36.0	47.0	43.0	7.3	6.4
10.0	46.0	42.0	57.0	50.0	65.0	59.0	4.4	3.8
16.0	61.0	56.0	76.0	68.0	87.0	79.0	2.8	2.4

Table 1.2 - Current ratings and volt drops for sheathed multi-core p.v.c.-insulated cables

Cross sectional area	In conduit in thermal insulation	In conduit in thermal insulation	In conduit on wall	In conduit on wall	Clipped direct	Clipped direct	Volt drop	Volt drop
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(mV/A/m)	(mV/A/m)
-	2 core	3 or 4 core	2 core	3 or 4 core	2 core	3 or 4 core	2 core	3 or 4 core
1.0	11.0	10.0	13.0	11.5	15.0	13.5	44.0	38.0
1.5	14.0	13.0	16.5	15.0	19.5	17.5	29.0	25.0
2.5	18.5	17.5	23.0	20.0	27.0	24.0	18.0	15.0
4.0	25.0	23.0	30.0	27.0	36.0	32.0	11.0	9.5
6.0	32.0	29.0	38.0	34.0	46.0	41.0	7.3	6.4
10.0	43.0	39.0	52.0	46.0	63.0	57.0	4.4	3.8
16.0	57.0	52.0	69.0	62.0	85.0	76.0	2.8	2.4

From table 1.2, 6 mm^2 p.v.c. twin with protective conductor has a current rating of 32 A. This is not quite large enough, so 10 $mm^2$with a current rating of 43 A is indicated. Not only would this add considerably to the costs, but would also result in difficulties due to terminating such a large cable in the accessories.

A more sensible option would be to look for a method of reducing the required cable size. For example, if the eight cables left the consumer unit in two bunches of four, this would result in a grouping factor of 0.65. Before applying this, we must check that the combined grouping and thermal insulation factors (0.65 x 0.89 = .0.58) are still less than the ambient temperature factor of 0.71, which is the case.

Table 1.3 - Current ratings of mineral insulated cables clipped direct

Cross-sectional area	Volt	p.v.c. sheath 2 x single or twin	p.v.c. Sheath 3 core	p.v.c. Sheath 3 x single or twin	Bare sheath 2 x single	Bare sheath 3 x single
(mm^2)		(A)	(A)	(A)	(A)	(A)
1.0	500v	18.5	16.5	16.5	22.0	21.0
1.5	500v	24.0	21.0	21.0	28.0	27.0
2.5	500v	31.0	28.0	28.0	38.0	36.0
4.0	500v	42.0	37.0	37.0	51.0	47.0
1.0	750v	20.0	17.5	17.5	24.0	24.0
1.5	750v	25.0	22.0	22.0	31.0	30.0
2.5	750v	34.0	30.0	30.0	42.0	41.0
4.0	750v	45.0	40.0	40.0	55.0	53.0
6.0	750v	57.0	51.0	51.0	70.0	67.0
10.0	750v	78.0	69.0	69.0	96.0	91.0
16.0	750v	104.0	92.0	92.0	127.0	119.0

Note that in tables 1.3 and 1.4 P.V.C. Sheath means bare and exposed to touch or having an over-all covering of p.v.c. or LSF and 'Bare' means bare and neither exposed to touch nor in contact with combustible materials.

Table 1.4 - Volt drops for mineral insulated cables

Cross-sectional area	Single-phase p.v.c. Sheath	Single-phase bare	Three-phase p.v.c. Sheath	Three-phase bare
(mm^2)	(mV/A/m)	(mV/A/m)	(mV/A/m)	(mV/A/m)
1.0	42.0	47.0	36.0	40.0
1.5	28.0	31.0	24.0	27.0
2.5	17.0	19.0	14.0	16.0
4.0	10.0	12.0	9.1	10.0
6.0	7.0	7.8	6.0	6.8
10.0	4.2	4.7	3.6	4.1

This leads to a cable current rating of $\frac{15}{0.65 \times 0.89}$ A = 25.9 A

This is well below the rating for 6 mm^2 of 32 A, so a cable of this size could be selected.

1.7. Cable Voltage Drop

All cables have resistance, and when current flows in them this results in a volt drop. Hence, the voltage at the load is lower than the supply voltage by the amount of this volt drop.

Many electricians wire for no more than 5% voltage drop. This is usually fine since appliances and power tools are made to operate over a range of voltages. For a more expensive way to wire a house, you can try wiring for no more than 2% voltage drop. In this case, if you are running 20 amps, you need to up the wire size to #10 if you go more than 35 feet. In general, the percentage voltage drop decreases with a higher starting voltage.

To see this, play around with the formula for voltage drop given in terms of resistance. The resistance of various sizes of wires can be found in the CRC handbook. Practically, this means you lose less power to voltage drop if you choose a 240 volt appliance instead of a 120 volt one. And you lose a lot with low voltage lighting running on 10 or 12 volts.

The volt drop may be calculated using the basic Ohm's law formula	
U = **I** x **R**	
where	**U** is the cable volt drop (V)
	I is the circuit current (A), and
	R is the circuit resistance □(Ohms)

Unfortunately, this simple formula is seldom of use in this case, because the cable resistance under load conditions is not easy to calculate.

To calculate the volt drop for a particular cable we use tables 1.1, 1.2 and 1.4. Each current rating table has an associated volt drop column or table. For example, multicore sheathed non-armored P.V.C. insulated cables are covered by table 1.2 for current ratings, and volt drops. The exception in the Regulations to this layout is for mineral insulated cables where there are separate volt drop tables for single- and three-phase operation, which are combined here as table 1.4.

To calculate the cable volt drop:

1. Take the value from the volt drop table (mV/A/m)

2. Multiply by the actual current in the cable (NOT the current rating)

3. Multiply by the length of run in meters

4. Divide the result by one thousand (to convert mill volts to volts).

For example, if a 4 mm² p.v.c. sheathed circuit feeds a 6 kW shower and has a length of run of 16 m, we can find the volt drop thus:

From table 1.2, the volt drop figure for 4 mm² two-core cable is 11 mV/A/m.

Cable current is calculated from $I = \frac{P}{U} = \frac{6000}{240}\text{ A} = 25\text{ A}$

Volt drop is then $\frac{11 \times 25 \times 16}{1000}\text{ V} = 4.4\text{ V}$

Maximum acceptable volt drop specified by the IEE Regulations is 2.5% of the system

CHAPTER TWO

BASIC REQUIRMENTS AND DISTRIBUTION BOARD

2.1. Basic Requirements for Circuits

The Regulations require that installations should be divided into circuits, the purposes being:

1. - to prevent danger in the event of a fault by ensuring that the fault current is no greater than necessary to operate the protective system. For example, a large three-phase motor must be connected to a single circuit because the load cannot be subdivided. If, however, a load consisted of three hundred lamps, each rated at 100 W, it would be foolish to consider putting all this load onto a single circuit. In the event of a fault, the whole of the lighting would be lost, and the fault current needed to operate the protective device (single-phase circuit current would be 125 A at 240 V) would be high enough to cause a fire danger at the outlet where the fault occurred. The correct approach would be to divide the load into smaller circuits, each feeding, perhaps, ten lamps.

2. - to enable part of an installation to be switched off for maintenance or for testing without affecting the rest of the system.

3. - to prevent a fault on one circuit from resulting in the loss of the complete installation.

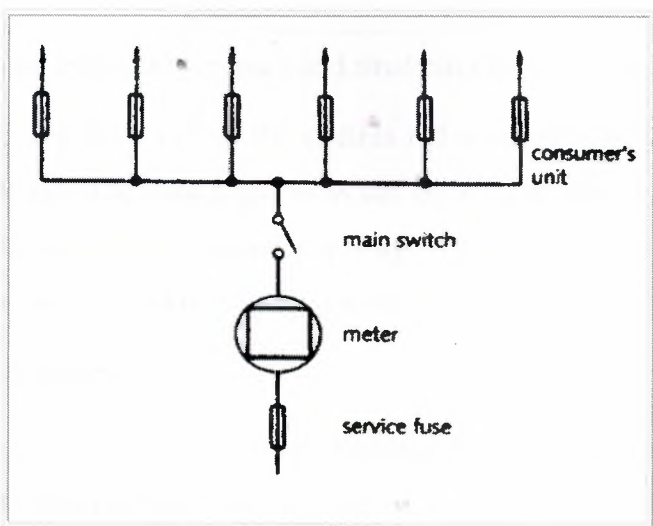

Fig 2.1: Typical arrangement for feeding final circuits in a domestic installation

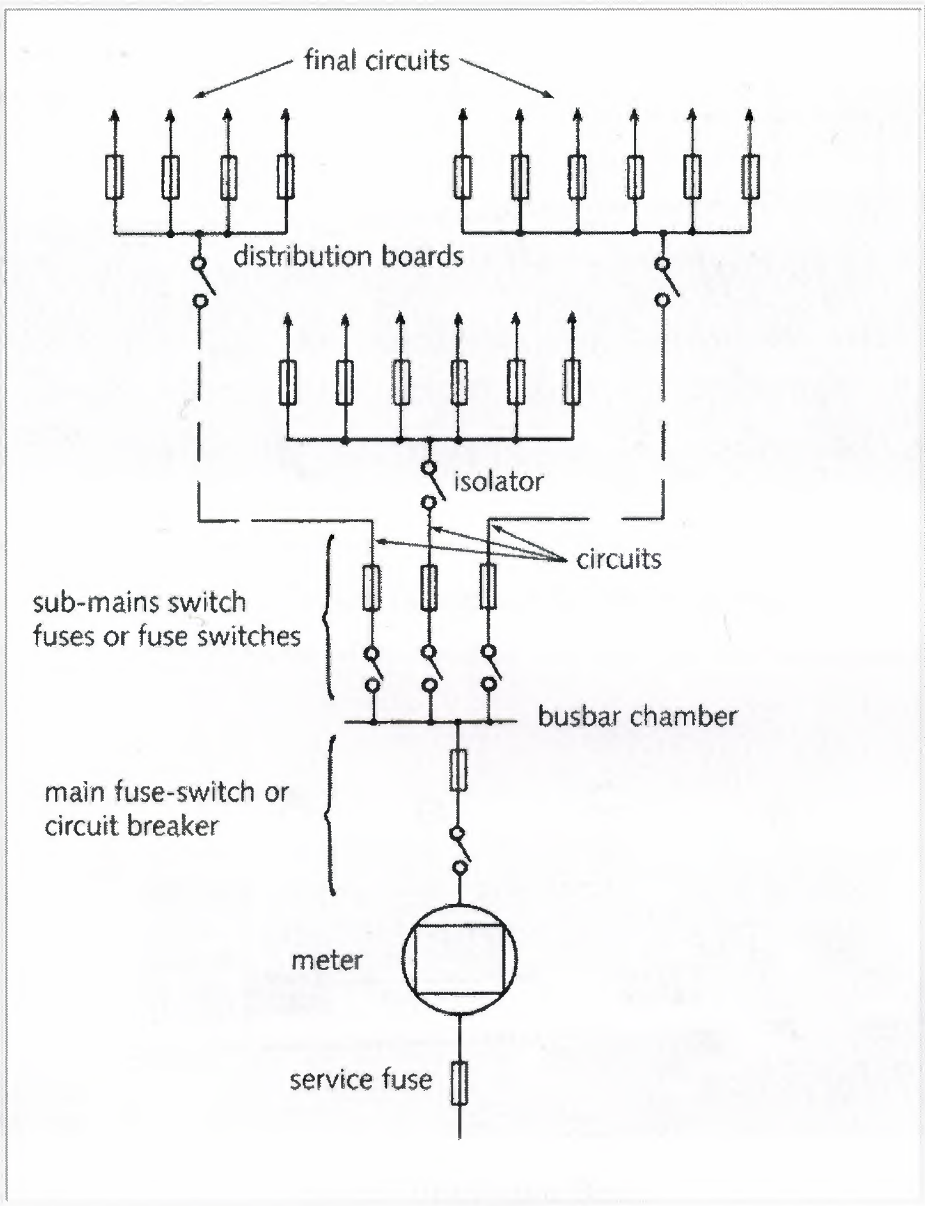

Fig 2.2: an arrangement for main and final circuits in a large installation

A durable notice giving details of all the circuits fed is required to be posted in or near each distribution board. The data required is the equipment served by each circuit, its rating, its design current and its breaking capacity. When the occupancy of the premises changes, the new occupier must be provided with full details of the installation.

2.2. Distribution Board

A distribution board divides the electrical mains feed into various circuits, providing a fuse or circuit breaker for each circuit. They usually include a main switch, and often one or more Residual-current devices (RCD).

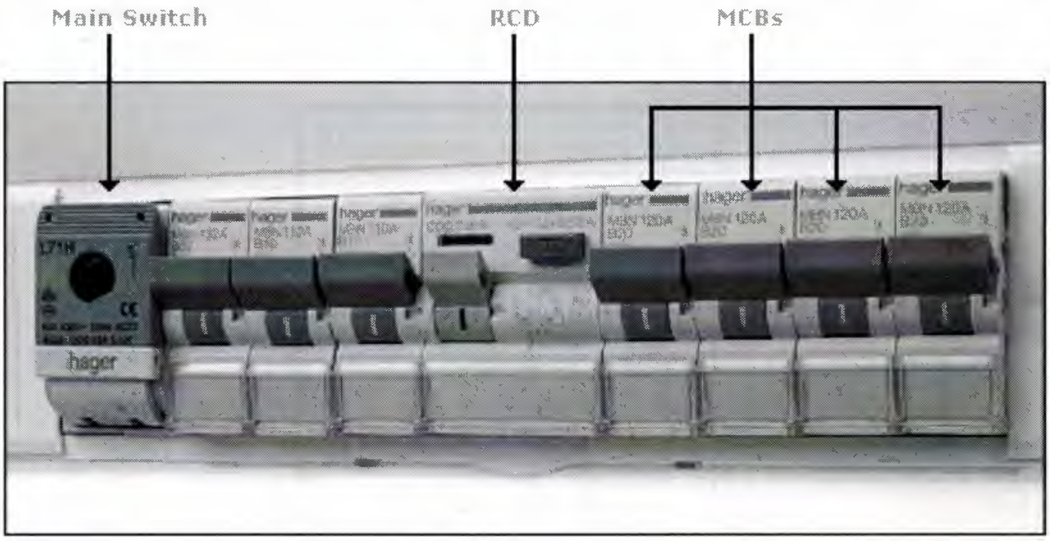

Figure 2.3: Typical Distribution Board- MCB Type

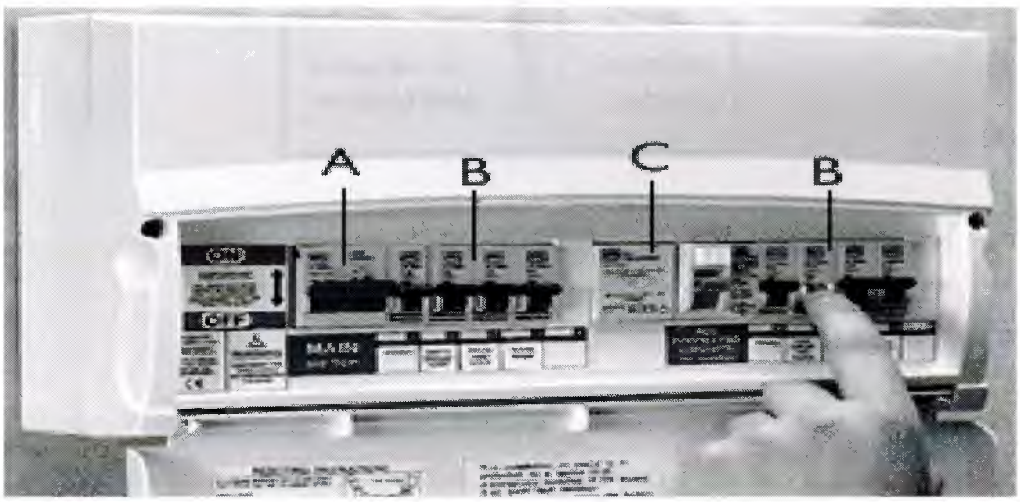

Figure2.4 Distribution Board

A = Main switch B = Circuit breakers C = Residual current device

Switches

The inside of a typical household wall switch has a strip of metal (B), making contact with point 'A', completing the circuit and thereby conducting electricity to the light. This would obviously be the 'ON' position. When the insulated lever is moved down to the 'OFF' position, it pushes the metal strip away from point 'A', breaking the circuit and turning the light 'OFF'.

This type of switch (having a lever which "flips" it on and off) is called a toggle switch.

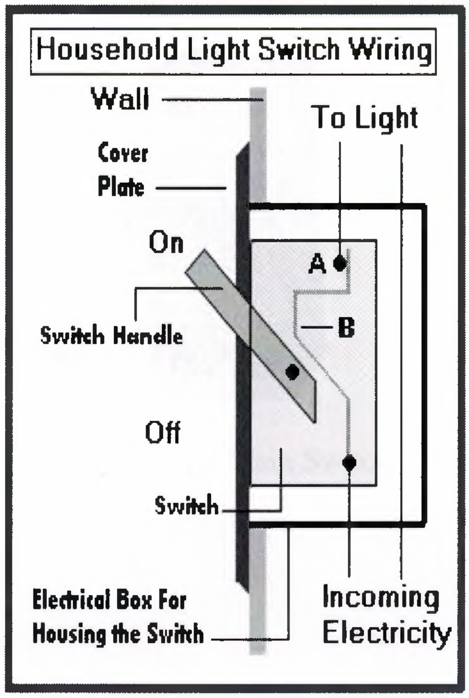

Figure 2.5: a House hold light switch

5 A switches may be obtained in the form of 1-Way, 2 ways, intermediate or double pole and dimmer control. Alternative methods of switch operation are dolly, rocker, and cord, pushbutton or key. In all cases an earth terminal connected to an appropriate circuit protective conductor is necessary.

Double-pole switches are available with dimensions similar to the 1-way switches, and a neon lamp may be fitted to them as part of a single assembly. Indicator lights are desirable as pilot lamps for no luminous heating or other appliances.

Where it is possible to touch the heating elements of radiators, double-pole control must be fitted.

2.2.1. Main Switch

The main switch allows you to turn off the electricity supply to the electrical installation. Note that some electrical installations may have more than one main switch.

For example, if the house is heated by electric storage heaters, it will probably have a separate main switch and consumer unit arranged to supply them.

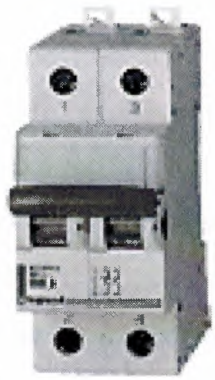

Figure 2.6: Main Switch

2.2.2. Circuit Breaker

Any electrical or electronic equipment that is designed without including circuit protection is an accident waiting to happen. Under normal operating conditions, this may not appear to be a problem. However, normal operating conditions are not always guaranteed. Under strained or heavy use, a motor and/or another load-generating component within the equipment will draw additional current from the power source; when this happens, the equipment's wires and/or components will overheat and may ultimately burn up. Also, power surges and short circuits in unprotected equipment can cause extensive damage to the equipment and to the conductors leading to the equipment. In addition to protecting the equipment, the entire electrical system including the control switches, wires, and power source must be protected from faults. A circuit protection device should be employed at any point where a conductor size changes. Many electronic circuits and components like transformers have a lower overload withstand threshold level than conductors such as wires and cables. These components require circuit protection devices featuring very fast overload sensing and opening capabilities. Specifying a circuit protection device for an application is not a difficult task, but it will require some thought. If electrical and electronic equipment is designed with over-specified circuit protection devices they will be vulnerable to the damaging effects of power surges and the catastrophic results of a fire; while using under-specified circuit protection devices will result in nuisance tripping. Before specifying a circuit protection device, equipment designers should evaluate the load characteristics during equipment startup and at normal operation. Many types of equipment will produce startup inrush current, or surges. In these cases, circuit breakers with the appropriate time delay should be selected. The time delay specified should slightly exceed the duration of the surge. Before specifying a circuit protection device, an equipment designer should also consider the following:

- Applied voltage rating (AC or DC)
- Single phase, multi-phase / number of poles
- Applicable national electric codes and safety
- regulatory agency standards
- Interrupting (short circuit) capacity
- Mounting requirements and position / enclosure size constraints

The short circuit capacity of a circuit protection device should be greater than the circuit's available short circuit fault current

A circuit breaker is defined as a device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined over current without injury to itself when properly applied within its rating. All circuit breakers have the following common design and functional characteristics:

- A frame
- Contacts and operating mechanisms
- Trip Units
- A method to extinguish an Arc
- A method for mounting
- Compliance with specific standards

The first four characteristics are components of the circuit breaker, which can be seen in the figure below. Let's look at each component separately.

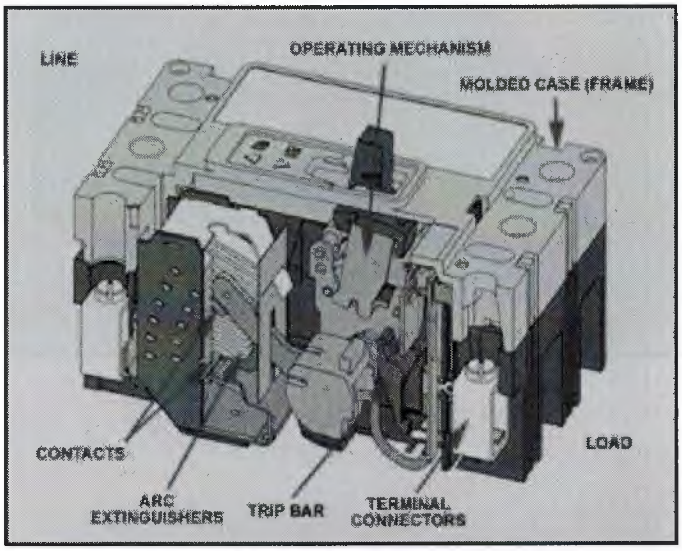

Figure 2.7: Characteristics of a Circuit Breaker

2.2.2.1. Frame

The rigid circuit breaker frame provides a method by which all the required components can be mounted and kept in place, ensuring the proper operation of the circuit breaker. The circuit breaker frame provides the rigidity and strength required to successfully deal with the interruption process and achieve the desired interrupting ratting The frame's mechanical strength must be sufficient to withstand the forces created by the square of the current (I^2), which could be quite large and potentially destructive. The frame also provides for insulation and isolation of the current path, offering personnel protection near the equipment during operation

Historically, there are two types of frames:

- Metal Frame
- Molded Insulating Material

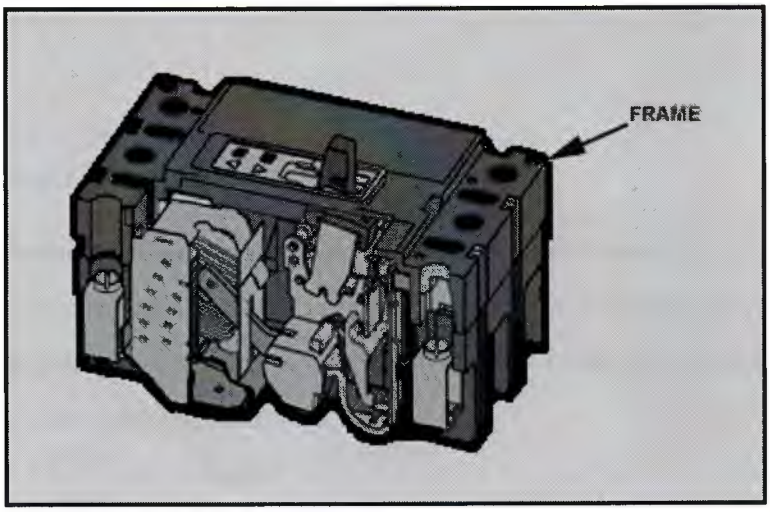

Figure 2.8: Circuit Breaker Frame

2.2.2.2. Contacts and Operating Mechanism

- **Contacts**

Contacts in a circuit breaker provide a method for connecting the circuit with the system. They also provide a method for isolating a part of a circuit from the rest of the system. A contact set contains a fixed and movable contact. As a circuit breaker opens or closes, the fixed contact maintains its position while the movable contact moves to close (make) or open (break) the circuit. When all is said and done, contacts perform a simple function; they open and close.

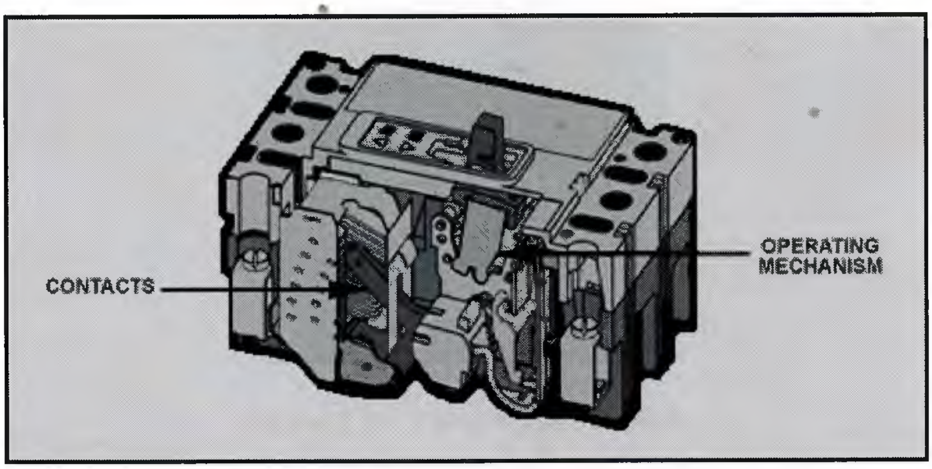

Figure 2.9: Contacts and Operating Mechanism

- **Operating Mechanism**

Circuit breakers require some type of operating mechanism to open and close the contacts. This operating mechanism can be mechanical or a combination of mechanical and power. Depending upon the type of circuit breaker being considered, the operating mechanism could be called upon to:

- Open and close the contacts manually
- Open and close the contacts on demand
- Open the contacts automatically

Let's consider a basic Three-Phase_circuit breaker. It is designed such that all three sets of contacts open or close simultaneously.

This requires that all the contacts be linked together in some manner. This part of the mechanism might be connected mechanically to a common handle. The handle, when operated, puts the mechanism into motion and opens or closes the circuit breaker by opening or closing the contacts.

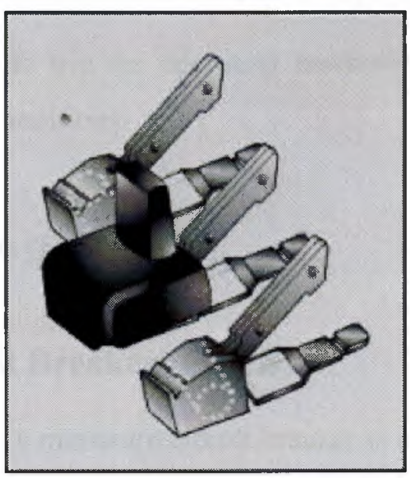

Figure 2.10: Three-Phase Contacts

This additional assistance takes the form of springs. Springs play a big role in the precise functioning of circuit breaker mechanisms. Springs are stretched or compressed to provide the energy necessary to assist with the proper opening or closing of the contacts.

2.2.2.3. Trip Units

For a circuit breaker to be effective, it needs to have some intelligence to enable it to perform automatically or respond to a command. Without this capability, a circuit breaker would just be a fancy switch. A trip unit is the circuit breaker's intelligence. We will discuss the function and the types of trip units.

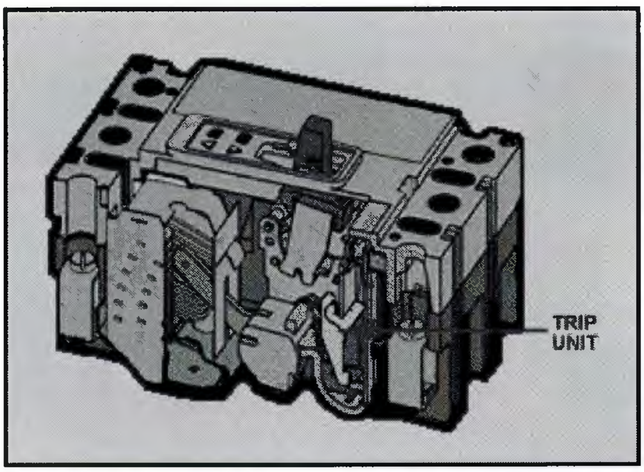

Figure 2.11Circuit Breaker Trip Units

The trip unit's function is to trip the operating mechanism (open the circuit) in the event of these over current conditions:

- Thermal Overload
- Short Circuit Currents (Fault Current)
- Ground Fault

2.2.3. Miniature Circuit Breakers (MCB)

As previously stated, a miniature circuit breaker is a device that switches and/or protects the lowest common distributed voltage in an electrical system. It is designed to protect conductors and insulation from damage due to Overload (or over current) and Short Circuit. Think about the electrical utility and where the electricity is generated.

The residential load center is certainly at the end of the distribution system. It is here that the voltages are the lowest of the distributed voltages in the electric utility's system. Miniature circuit breakers are not just for residential applications only. They are used in residential, commercial and industrial applications. In an industrial or commercial application, miniature circuit breakers can be found in load centers, lighting Panel boards and individual mountings.

Figure 2.12: Typical Miniatures Molded Case Circuit Breakers

Applications

Miniature circuit breakers fall into two categories. These are:

- **Residential**-Residential miniature breakers are only of the Plug-In type. These are designed for residential load centers, commercial units, and light industrial applications. They typically range from 10 to 125 amps, with an interrupting rating of 10 or 22 KAIC.
- **Industrial**-These breakers are designed for three types of mounting applications: plug-in, Bolt-On, and Cable-In/Cable-Out. (We will look at mounting methods shortly.)

Industrial miniature breakers are designed to protect small branch circuits in commercial or industrial electrical distribution systems. They are applied in load centers, lighting panel boards or individual mounting applications. They typically range from 6 to 125 amps, with an interrupting ratings as high as 65 KAIC. Some potential customers are original equipment manufacturers (OEMs) involved in industrial control panels and electrical machinery, such as machine tool equipment, material handling and packaging systems. In addition, look for involvement with printing machines, food-processing systems, uninterruptible power supplies (UPS) and HVAC (heating, ventilation and air conditioning). Each miniature breaker is rated to handle a specific load. For example, a circuit breaker protecting a branch used with kitchen appliances has a higher rating than a circuit breaker protecting a branch with an overhead lighting fixture on it.

2.2.3.1. Components

Miniature circuit breaker construction is simple, yet very precise. In fact, a miniature circuit breaker has no replacement parts. It is not designed to be maintained. When a unit goes badly, it is simply replaced.

A typical miniature circuit breaker has three main components. These are:

1. Frame

The Frame has a molded case exterior. Its primary function is to provide a rigid, mechanically strong, insulated housing in which the other components are mounted.

2. Operating Mechanism

The Operating Mechanism provides the means of opening and closing the circuit. It has a three-position switch ("on," "off," and "tripped"). It can only be in the "tripped" position as a result of an over current. When power is removed manually, it can only be switched to the "off" position. This makes it is easy for a maintenance person to determine why power has been cut.

3. Trip Unit

The Trip Unit is the brain of the miniature circuit breaker. It activates the operating mechanism in the event of a prolonged overload or short circuit. This type of circuit breaker uses a Thermal Magnetic_mechanism. This is the predominant trip unit technology used in the domestic market. A bimetal and an electromagnet work together to provide overload and short-circuit protection. (The principles of how this works can be found in Module 5, Fundamentals of Circuit Breakers.)

2.2.3.2. Categorizing Miniature Circuit Breakers

Specifications for miniature circuit breakers vary widely. As such, there is a miniature circuit breaker to fit virtually any application, standard and local code requirement. In general, miniature circuit breakers are often categorized by the following:

- Ratings
- Number of poles

1. Ratings

Every circuit breaker has specific ampere, voltage, and interrupting ratings. The Ampere Rating is the breaker's continuous current-carrying capability. In most cases, the ampere rating should not exceed the current-carrying capacity of the circuit. For example, if a conductor is rated at 10 amps, select a circuit breaker no larger than 10 amps. Ampere ratings for miniature circuit breakers range from 10 to 150 amps. There are some specific circumstances when the ampere rating is permitted to be greater than the current-carrying capacity of the circuit. For example, motor and welder circuits can exceed conductor ampacity. This allows for inrush currents and duty cycles. Limits are established by the NEC (National Electrical Code).The Voltage Rating of a circuit breaker must be at least equal to the circuit voltage. It can be higher than the circuit voltage, but never lower. For example, a 480-volt breaker can be used in a 240-volt circuit. However, a 240-volt breaker could not be used in a 480-volt circuit. Voltage ratings for miniature circuit breakers are 120/240-volt and 240-volt. A circuit breaker is also rated according to the level of fault current it can interrupt. This is referred to as

Ampere Interrupting Capacity (AIC) (also called "interrupting rating"). In an application, a breaker must be able to interrupt the circuit's maximum short circuit current (without damaging itself). Interrupting ratings for miniature circuit breakers are 10, 22, 42, and 65 KAIC (thousand amps interrupting capacity).

2. Poles

Miniature circuit breakers are typically available in Single Pole, Double Pole, and three pole types. A pole is a hot conductor. It is a space in a load center, panel board, or similar device where a breaker can be attached. A single pole breaker disconnects one conductor, and a double pole breaker disconnects two conductors. A three pole breaker is typically used in industrial applications.

Single pole breakers are associated with 120 volts, while double pole breakers are associated with 240 volts. (For more detail on this subject, refer to Module 10, Load centers.).Miniature circuit breaker poles are generally one inch in width. However, some residential type breaker designs allow two poles to fit in the standard one-inch space. This breaker type is called a Duplex Circuit Breaker_(or "half-size branch circuit breaker"). Twice as many protective devices fit in the same amount of available space, with the same ampere rating and without sacrificing protection or features (Figure 6). However, these narrow design configurations have current, voltage, and interrupting capacity limitations.

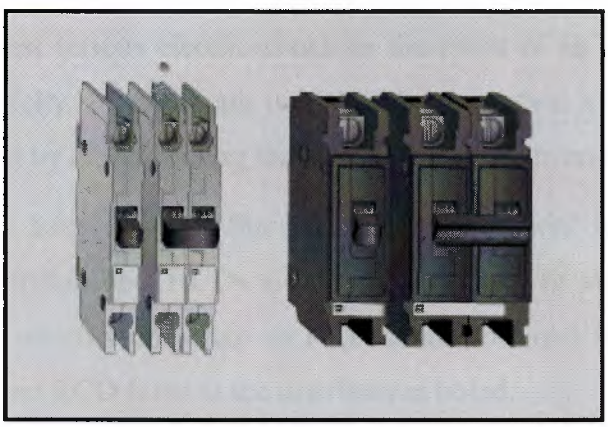

Figure 2.13: 1/2 Inch per Pole and 1 Inch per Pole Circuit Breakers, Same Ampere Rating (1/2 Inch on Left)

2.2.3.3. Special Application Breakers and Accessories

In addition to the general use miniature circuit breaker, there are a number of breaker types that have been designed for a particular application. These include:

- **Ground Fault Circuit Interrupter (GFCI)**-This breaker has a solid state trip unit. It detects ground currents (which are small short circuits from one phase to ground), and trips to protect both people and equipment.

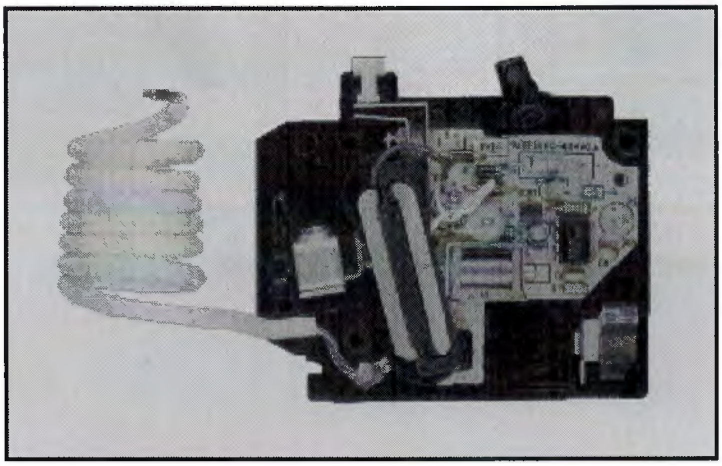

Figure 2.14: GFCI Breakers

2.2.4. Residual Current Devices (RCDs)

RCDs guard against serious electric shock in the event of an electrical fault. They detect 'leaking' electricity from a circuit (which can occur when a cable is damaged for example) and respond by disconnecting the electricity supply from the circuit.

Most modern homes have an RCD fitted in their distribution/ fuse board, but older homes may need to install one. RCDs are also available to fit at a socket outlet as a plug- in item. Plugs which incorporate an RCD should be used for tools and outdoor equipment if there is no RCD fitted at the distribution board.

2.2.4.1. To Test RCD

It is crucial to check whether the RCD is working correctly. To perform this check we press the test button marked 'T' or 'Test' on the RCD fitted at the distribution/ fuse board, all RCDs have one. If it is working correctly, the power to all socket circuits will immediately switch off. If the RCD fails to trip have it replaced immediately by a registered electrical contractor. Remember reset the RCD after testing to restore power!

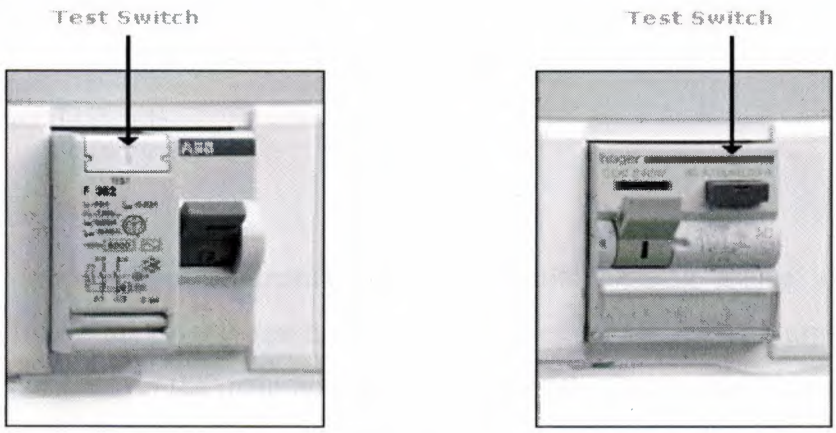

Figure 2.15: Residual Current Devices' test buttons.

CHAPTER THREE

SOCKETS AND LIGHTING CIRCUITS

3.1. Socket Outlet Circuits

There are two main types of circuits used in connecting sockets. Those are: ring circuits and radial circuits.

3.1.1. Ring Circuit

Most modern socket circuits are ring circuits or ring mains as they are sometimes referred to. As we see in figure 3.1 cables leaves the consumer unit and travels to each socket on the main and when it reaches the last socket it then returns to the consumer unit, thus creating a ring. The advantage of this system is that power can reach the sockets in the circuit from both directions, which reduces the power load on thecables

A ring circuit can serve an area up to 110 square meters (120 square yards), 2.5mm2 cable is used to wire the circuit and the circuit has a 30amp fuse or 32amp MCB on the consumer unit. It is usual for a house to have one ring circuit upstairs and one ring circuit downstairs.

Ring circuits can have extra sockets added to them by adding a 'spur' onto a ring circuit. A spur is a branch off the ring circuit, usually from an existing circuit, although a junction box could also be used. Theoretically as many spurs as sockets could be added, but the maximum load of the circuit (30/32amp) still exists.

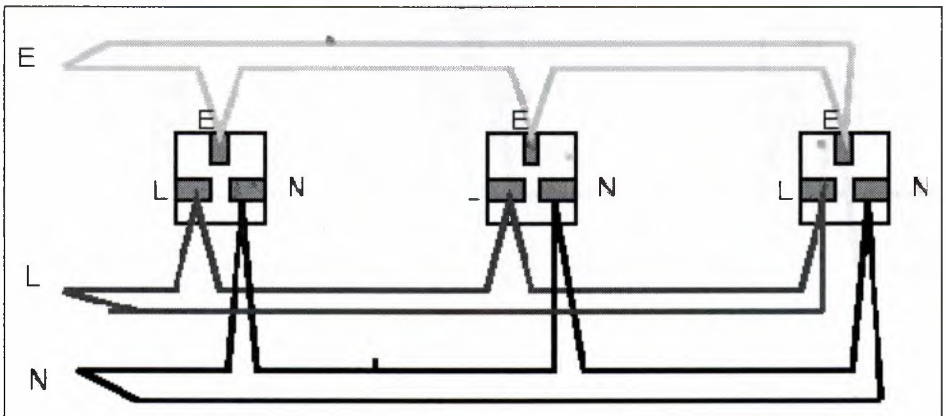

Figure 3.1: Connection of a ring power circuit

3.1.2. Radial Circuit

A radial circuit is a mains power circuit found in some homes to feed sockets and lighting points. It is simply a length of appropriately rated cable feeding one power point then going on to the next. The circuit terminates with the last point on it. It does not return to the consumer_unit or fuse box as does the more popular circuit, the ring main. To see the wiring at the back of the socket please go to the ring main project.

The descriptions below apply only to a circuit for power sockets. Lighting are dealt with in a separate project.

There is no limit to the number of sockets used on a radial circuit providing the circuit is contained within an area not exceeding 50 square m, and, just like a ring main, spurs, or extra sockets, can be added. The number of spurs must not exceed the number of existing sockets. The images below are all rated for use with a radial circuit

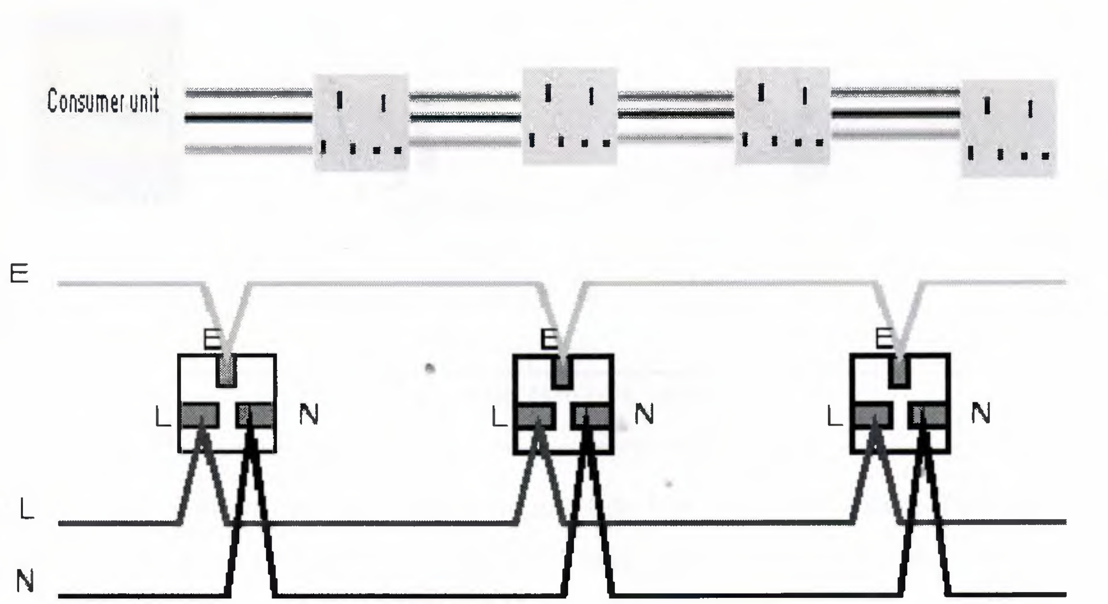

Figure 3.2 connection of a radial power circuit

3.2. Lighting Circuits

To understand fully how a lighting circuit works you need to understand about the principle of switching. This can be seen in our_lights and switches project Light switches, sockets, cables and tools

There are two types of popular lighting circuit. The first one, shown below, takes power from the consumer unit to the first ceiling rose. It is then taken from the ceiling rose, through the switch and back to the ceiling rose where it then carries on to the next ceiling rose. This carries on until it is looped all round the house and is called the loop circuit or system.

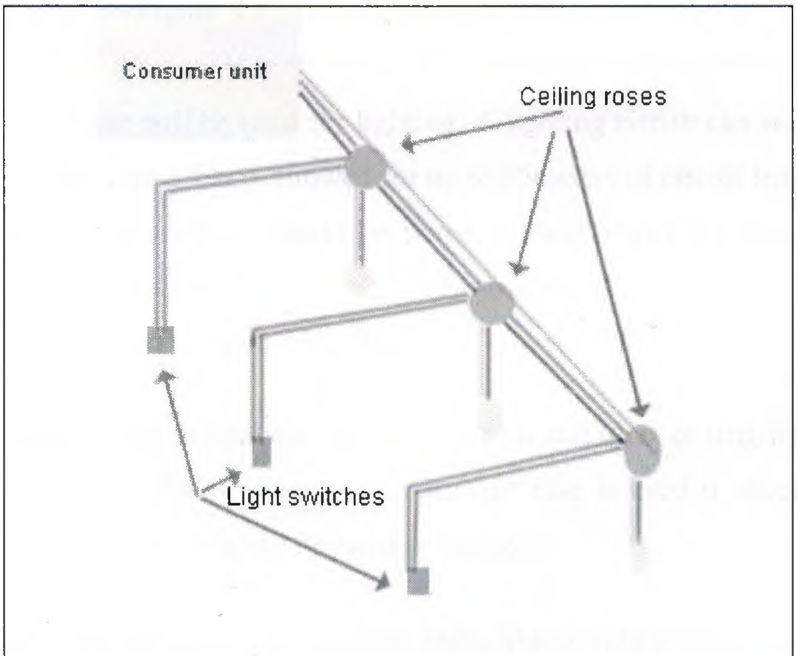

Figure3.3: connection of a lighting circuit

The second system in popular use is the junction box circuit or system. Power is taken from the consumer unit to the first junction box. The live is interrupted by the switch wiring and the circuit is carried on to the next junction box. A cable is run from the junction box to the light, usually via a ceiling rose.

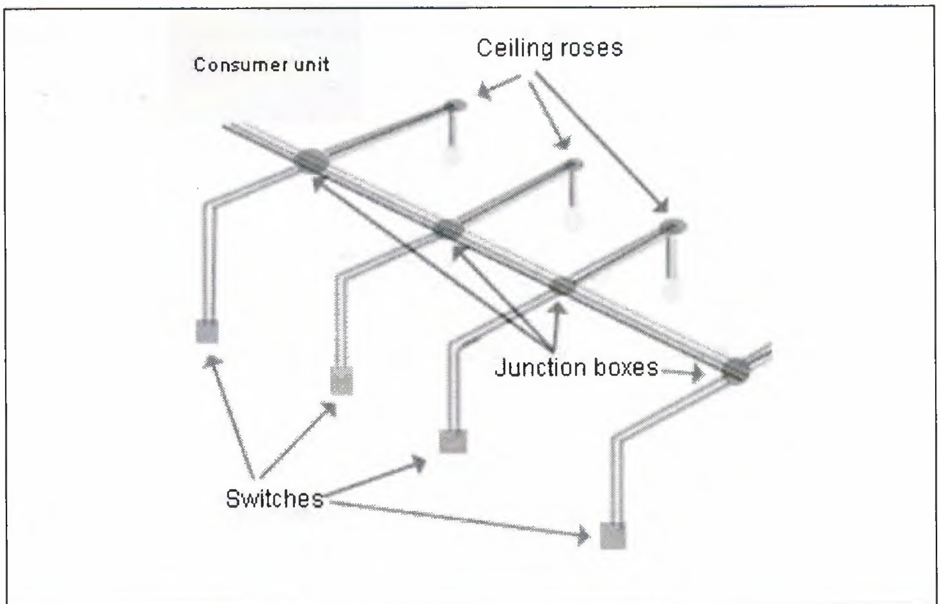

Figure 3.4 connection of a lighting circuit

Usually 1mm sq. cable will be used for lighting. A lighting circuit can serve up to 12 x 100W bulbs. Using 1mm cable is allowed for up to 95meters of circuit length. This does not include the switches which should be wired in switch wire which contains 2 red cores. If you have longer lengths to cover, 1.5mm squared cable can be used and the maximum length allowed using this is 110m.

To avoid the house being in total darkness if a fuse should blow or trip, lighting circuits are split into upstairs and downstairs. If a cartridge fuse is used it should be rated at 5amps, if an MCB is used it should be rated at 6amps.

Lighting circuits may include fixed lighting units, like ceiling pendants and uplighters, and outlets for flexible lighting systems (like track lighting). These circuits are often more complicated to construct, because they include a switch. In theory, the wiring of a lighting circuit can be viewed as figure 3.5.

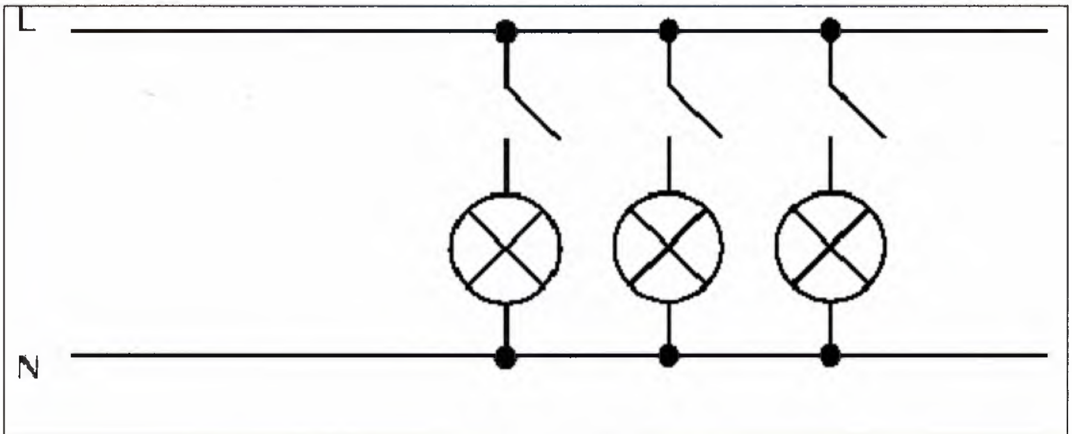

Figure 3.5 A theoretical lighting circuit with switches

As can be seen from the figure, the switch is on the live and not on the neutral part of the circuit. This ensures that the light fitting is safe when the switch is off (so, for example, the bulb can be changed without risk of electrocution).

In practice it would be very difficult to wire a lighting circuit like figure 3.5, because the live and neutral cables are separate. In addition, an earth connection is needed at each switch, and each light fitting, for safety reasons (not shown on diagram). Normally we use two-core-and-earth cable for domestic wiring, so by convention the wiring of a lighting circuit is as shown in figure 3.6.

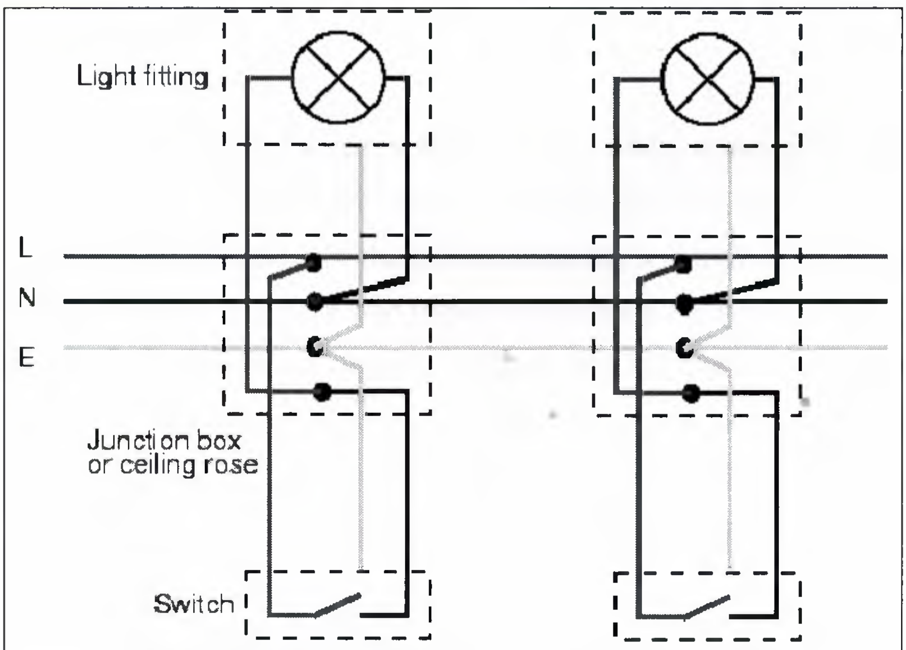

Figure 3.6: A more practical lighting circuit

Apart from only showing two lights rather than three, this configuration is identical to figure 3.5, although it looks more complex. This additional complexity is to ensure that all connections can be made with two-core-and-earth cable. The central point for each light fitting is a junction box with four terminals. There are two ways to implement this junction box. First, a specific four-terminal lighting junction box can be used. The junction box will normally be concealed in a ceiling or floor void. Second, an integrated ceiling rose can be used, where the terminal blocks are part of the rose body. The rose connects the pendant lamp holder, and hides all the connections. For simplicity, the rose will often be supplied with exactly the right number of terminals to accommodate all the cable connections. That is, there will be two blocks of three terminals, one block of two, and one block of four (for the earth wires).

One important point to note about the standard lighting circuit is that when the switch is on, both wires (red and black) to the switch are live. If this situation (a black live wire) is found to be unpalatable, one can buy a two-core-and-earth cable with two red conductors. Alternatively - at much lower cost - a small red marker (e.g., red insulating tape) could be wrapped around the black wire wherever it is visible.

When integrated ceiling roses are used throughout a circuit, this is called a `loop-in' configuration. Note, again, that the only connections are inside the fittings; there are no concealed junction boxes.

Lighting circuits are usually wired with 1.5 mm^2 cable, although 1 mm^2 is not uncommon. In conditions where the cable is entirely enclosed in wall plaster, at 30 degrees Celsius even the smaller of these two cables has a current carrying capacity of 11 amps: still well below the likely load imposed by a standard lighting circuit (11 amps will support more than twenty 100-watt light bulbs). However, if the cable run is long, it is more likely to exceed the maximum voltage drop regulation. In a worst-case configuration (a long cable with maximum allowable current drawn at the far end) it turns out that a 1 mm^2 cable can be about 35 meters long before this happens. If the cable is longer than that, a larger cable is needed.
Lighting circuits are not normally wired as a ring system, because the total current requirement rarely even approaches the capacity of the cable.

CHAPTER FIVE

Lighting Glossary

Term	Definition
Accent Lighting	Directional lighting to emphasize a particular object or to draw attention to a part of the field of view.
Absorption	The dissipation of light within a surface or medium.
Accommodation	The process by which the eye changes focus from one distance to another.
Adaptation	The process by which the visual system becomes accustomed to more or less light than it was exposed to during an immediately preceding period. It results in a change in the sensitivity of the eye to light.
Alternating Current (AC)	Flow of electricity which cycles or alternates direction many times per second. The number of cycles per second is referred to as frequency. Most common frequency used in this country is 60 Hertz (cycles per second).
Ambient Lighting	Background or fill light in a space.
Amperes (amps or A)	The unit of measurement of electric current.
Back Lighting	The illumination provided for scenery in off-stage areas visible to the audience.
Baffle	An opaque or translucent element that serves to shield a light source from direct view at certain angles, or serves to absorb unwanted light.
Ballast	An auxiliary device consisting of induction windings wound around a metal core and sometimes includes a capacitor for power correction. It is used with fluorescent and HID lamps to provide the necessary starting voltage and to limit the current during operation.
"Batwing" Distribution	Candlepower and distribution which serves to reduce glare and veiling reflections by having its maximum output in the 30° to 60° zone.
Candela	The unit of measurement of luminous intensity of a light source in a given direction.
Candlepower	Luminous intensity expressed in candelas.

Candlepower Distribution Curve	A curve, generally polar, representing the variation of luminous intensity of a lamp or luminaire in a plane through the light center.
Cavity Ratio	A number indicating cavity proportions calculated from length, width and height.
Class "P" Ballast	Contains a thermal protective device which deactivates the ballast when the case reaches a certain critical temperature. The device resets automatically when the case temperature drops to a lower temperature.
Coefficient of Utilization (CU)	The ratio of the luminous flux (lumens) from a luminary calculated as received on the work-plane to the luminous flux emitted by the luminaries lamps alone.
Cold Cathode Lamp	An electric-discharge lamp whose mode of operation is that of a flow discharge.
Colorimetric	The measurement of color.
Color Rendering Index (CRI)	Measure of the degree of color shift objects undergo when illuminated by the light source as compared with the color of those same objects when illuminated by a reference source of comparable color temperature.
Color Temperature	The absolute temperature of a blackbody radiator having a chromaticity equal to that of the light source.
Cone Reflector	Parabolic reflector that directs light downward thereby eliminating brightness at high angles.
Contrast	The difference in brightness (luminance) of an object and its background.
Cool Beam Lamps	Incandescent PAR lamps that use a special coating (diachronic interference filter) on the reflector zed potion of the bulb to allow heat to pass out the back while reflecting only visible energy to the task, thereby providing a "cool beam" of light.
Cove Lighting	Lighting comprising sources shielded by a ledge or horizontal recess, and distributing light over the ceiling and upper wall.
Cutoff Luminaries	Outdoor luminaries that restrict all light output to below 85° from vertical.
Digital Addressable Lighting Interface (DALI)	An open communications protocol used by multiple control and ballast manufacturers for digital control.
Dimming Ballast	Special fluorescent lamp ballast, which when used with a dimmer control, permits varying light output.
Direct Current (DC)	Flow of electricity continuously in one direction from positive to negative.
Direct Lighting	Lighting involving luminaries that distribute 90 to 100% of

	emitted light in the general direction of the surface to be illuminated. The term usually refers to light emitted in a downward direction.
Direct Glare	Glare resulting from high luminances or insufficiently shielded light sources in the field of view. It usually is associated with bright areas, such as luminaries, ceilings and windows which are outside the visual tasks or region being viewed.
Discharge Lamp	A lamp in which light (or radiant energy near the visible spectrum) is produced by the passage of an electric current through a vapor or a gas.
Discomfort Glare	Glare producing discomfort. It does not necessarily interfere with visual performance or visibility.
Emergency Lighting	Lighting system designed to provide minimum illumination required for safety, during power failures.
Efficacy	See Lamp Efficacy.
Efficiency	See Luminaries Efficiency.
Equivalent Sphere Illumination (ESI)	The level of sphere illumination which would produce task visibility equivalent to that produced by a specific lighting environment.
"ER" (Elliptical Reflector)	Lamp whose reflector focuses the light about 2" ahead of the bulb, reducing light loss when used in deep baffle downlights.
Extended Life Lamps	Incandescent lamps that have an average rated life of 2500 or more hours and reduced light output compared to standard general service lamps of the same wattage.
Fill Light	Illumination added to reduce shadows or contrast range.
Floodlighting	A system designed for lighting a scene or object to a luminance greater than its surroundings. It may be for utility, advertising or decorative purposes.
Fluorescent Lamp	A low-pressure mercury electric-discharge lamp in which a phosphor coating transforms some of the ultraviolet energy generated by the discharge into light.
Foot candle (fc)	The unit of luminance when the foot is taken as the unit of length. It is the luminance on a surface one square foot in area on which there is a uniformly distributed flux of one lumen.
Foot Lambert (fl)	A unit of luminance of perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square foot.
Footlights	A set of strip lights at the front edge of the stage platform used to soften face shadows cast by overhead luminaries and to add general toning lighting from below.
General Lighting	See Ambient Lighting.

General Service Lamps	"A" or "PS" incandescent lamps.
Glare	The sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility.
Ground Relamping	Relamping of a group of luminaries at one time or reduce relamping labor costs.
High Intensity Discharge (HID) Lamp	A discharge lamp in which the light producing arc is stabilized by wall temperature and the arc tube has a bulb wall loading in excess of three watts per square centimeter. HID lamps include groups of lamps known as mercury, metal halide, and high pressure sodium.
High Output Fluorescent Lamp	Operates at 800 or more mill amperes for higher light output than standard fluorescent lamp (430MA).
High Pressure Sodium (HPS) Lamp	High intensity discharge (HID) lamp in which light is produced by radiation from sodium vapor. Includes clear and diffuse-coated lamps.
Incandescence	The self-emission of radiant energy in the visible spectrum due to the thermal excitation of atoms or molecules.
Incandescent Lamp	A lamp in which light is produced by a filament heated to incandescence by an electric current.
Instant Start Fluorescent Lamp	A fluorescent lamp designed for starting by a high voltage without preheating of the electrodes.
Inverse Square Law	The law stating that the luminance at a point on a surface varies directly with the intensity of a point source, and inversely as the square of the distance between the source and the point. If the surface at the point is normal to the direction of the incident light, the law is expressed by fc=cp/d2.
Kelvin	Unit of measurement for color temperature. The Kelvin scale starts from absolute zero, which is -273° Celsius.
Kilowatt-Hour (KWH)	Unit of electrical power consumed over a period of time. KWH = watts/1000 x hours used.
Lamp	An artificial source of light (also portable luminary equipped with a cord and plug).
Lamp Efficacy	The ratio of lumens produced by a lamp to the watts consumed. Expressed as lumens per watt (LPW).
Lamp Lumen Depreciation (LLD)	Multiplier factor in illumination calculations for reduction in the light output of a lamp over a period of time.
Light	Radiant energy that is capable of exciting the retina and producing a visual sensation. The visible portion of the electromagnetic spectrum extends from about 380 to 770 nm.

Lens	Used in luminaries to redirect light into useful zones.
Local Lighting	Lighting designed to provide luminance over a relatively small area or confined space without providing any significant general surrounding lighting.
Louver	A series of baffles used to shield a source from view at certain angles or to absorb unwanted light. The baffles usually are arranged in a geometric pattern.
Long Life Lamps	See Extended Life Lamps.
Low Pressure Sodium Lamp	A discharge lamp in which light is produced by radiation of sodium vapor at low pressure producing a single wavelength of visible energy, i.e. yellow.
Low Voltage Lamps	Incandescent lamps that operate at 6 to 12 volts.
Lumen	The unit of luminous flux. It is the luminous flux emitted within a unit solid angle (one steroidal) by a point source having a uniform luminous intensity of one candela.
Lumina ire	A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.
Lumina ire Direct Depreciation (LDD)	The multiplier to be used in luminance provided by clean, new luminaries to the reduced luminance that they will provide due to direct collection on the luminaries at the time at which it is anticipated that cleaning procedures will be instituted.
Lumina ire Efficiency	The ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the lamp or lamps used.
Luminance	The amount of light reflected or transmitted by an object.
Lux	The metric unit of luminance. One lux is one lumen per square meter (lm/m2).
Maintenance Factor (MF)	A factor used in calculating luminance after a given period of time and under given conditions. It takes into account temperature and voltage variations, dirt accumulation on luminaire and room surfaces, lamp depreciation, maintenance procedures and atmosphere conditions.
Mercury Lamp	A high intensity discharge (HID) lamp in which the major portion of the light is produced by radiation from mercury. Includes, clear, phosphor-coated and self-ballasted lamps.
Metal Halide Lamp	A high intensity discharge (HID) lamp in which the major portion of the light is produced by radiation of metal halides and their products of dissociation-possible in combination with metallic vapors such as mercury. Includes clear and phosphor coated lamps.
Nadir	Vertically downward directly below the luminaries or lamp; designated as 0°.

Overall Length (OAL)	Maximum overall length of a light fixture.
"PAR" Lamps	Parabolic aluminized reflector lamps which offer excellent beam control come in a variety of beam patterns from very narrow spot to wide flood and can be used outdoors unprotected because they are made of "hard" glass that can withstand adverse weather.
Parabolic Louvers	A grid of baffles which redirect light downward and provide very low luminary brightness.
Photometry	The measurement of light quantities.
Point Method Lighting Calculation	A lighting design procedure for predetermining the luminance at various locations in lighting installations, by use of luminary photometric data.
Polarization	The process by which the transverse vibrations of light waves are oriented in a specific plane. Polarization may be obtained by using either transmitting or reflecting media.
Power Factor	Ratio of: Watts (volts x amperes) Power factor in lighting is primarily applicable to ballasts. Since volts and watts are usually fixed, amperes (or current) will go up as power factor goes down. This necessitates the use of larger wire sizes to carry the increased amount of current needed with Lowe Power Factor (L.P.F) ballasts. The addition of a capacitor to an L.P.F. ballast converts it to a H.P.F. ballast.
Preheat Fluorescent Lamp	A fluorescent lamp designed for operation in a circuit requiring a manual or automatic starting switch to preheat the electrode in order to start the arc.
"R" Lamps	Reflectorized lamps available in spot (clear face) and flood (frosted face).
Rapid Start Fluorescent Lamp	A fluorescent lamp designed for operation with a ballast that provides a low-voltage winding for preheating the electrodes and initiating the arc without a starting switch or the application of high voltage.
Raw Footcandles	See Footcandles.
Reflection	Light bouncing off a surface. In specular reflection the light strikes and leaves a surface at the same angle. Diffuse reflected light leaves a surface in all directions.
Reflectance	Sometimes called reflectance factor. The ratio of reflected light to incident light (light falling on a surface). Reflectance is generally expressed in percent.
Reflected Glare	Glare resulting from specular reflections of high luminances in polished or glossy surfaces in the field of view. It usually is associated with reflections from within a visual task or areas in close proximity to the region being viewed.

Reflector	A device used to redirect the light flow from a source by bouncing it off the surface.
Refraction	The process by which the direction of a ray of light changes as it passes obliquely from one medium to another in which its speed is different.
Room Cavity Ration (RCR)	A number indicating room cavity proportions calculated from length, width and height.
Rough Service Lamps	Incandescent lamps designed with extra filament supports to withstand bumps, shocks and vibrations with some loss in lumen output.
Self-ballasted Mercury Lamps	Any mercury lamp of which the current-limiting device is an integral part.
Silver Bowl Lamps	Incandescent "A" lamps with a silver finish inside the bowl or portion of the bulb. Used for indirect lighting.
Spacing Ratio	Ratio of the distance between luminaire centers to the mounting height above the work-plane for uniform illumination.
Spectral Energy Distribution (SED) Curves	A plot of the level of energy at each wavelength of a light source.
Sphere Illumination	The illumination on a task from a source providing equal luminance in all directions about that task, such as an illuminated sphere with the task located at the center.
Surface Mounted Luminaire	A luminaire that is mounted directly on a ceiling.
Suspended (Pendant) Luminaire	A luminaire that is hung from a ceiling by supports.
Task Lighting	Lighting directed to a specific surface or area that provides illumination for visual tasks.
Three-Way Lamps	Incandescent lamps that have two separately switched filaments permitting a choice of three levels or light such as 30/70/100, 50/100/150 or 100/200/300 watts. They can only be used in a base down position.
Transformer	A device to raise or lower electric voltage.
Transmission	The passage of light through a material.
Tungsten-Halogen Lamp	A gas filled tungsten incandescent lamp containing a certain proportion of halogens.
Veiling Reflections	Regular reflections superimposed upon diffuse reflections from an object that partially or totally obscure the details to be seen by reducing the contrast. This is sometimes called reflected glare.

Vibration Service Lamps	See Rough Service Lamps.
Visual Comfort Probability (VCP)	The rating of a lighting system expressed as a percent of people who, when viewing from the specified location and in a specified direction, will be expected to find it acceptable in terms of discomfort glare.
Visual Edge	The line on a isolux chart which has a value equal to 10% of the maximum illumination.
Visual Field	The field of view that can be perceived when the head and eyes are kept fixed.
Wall Wash Lighting	A smooth even distribution of light over a wall.
Watt (W)	The unit for measuring electric power. It defines the power or energy consumed by an electrical device. The cost of operating an electrical device is determined by the watts it consumes times the hours or use. It is related to volts and amps by the following formula: Watts = Volts x Amps.
Zonal Cavity Method Lighting Calculation	A lighting design procedure used for predetermining the relation between the number and types of lamps or luminaires, the room characteristics, and the average illuminance on the work-plane. It takes into account both direct and reflected flux.

CHAPTER ONE

LIGHT AND CABLES

1.1. Light

What is light: Light is a form of radiant energy that travels in waves made up of vibrating electric and magnetic fields? These waves have both a frequency and a length, the values of which distinguish light from other forms of energy on the electromagnetic spectrum. Visible light, as can be seen on the electromagnetic spectrum, represents a narrow band between ultraviolet light (UV) and infrared energy (heat). These light waves are capable of exciting the eye's retina, which results in a visual sensation called sight. Therefore, seeing requires a functioning eye and visible light.

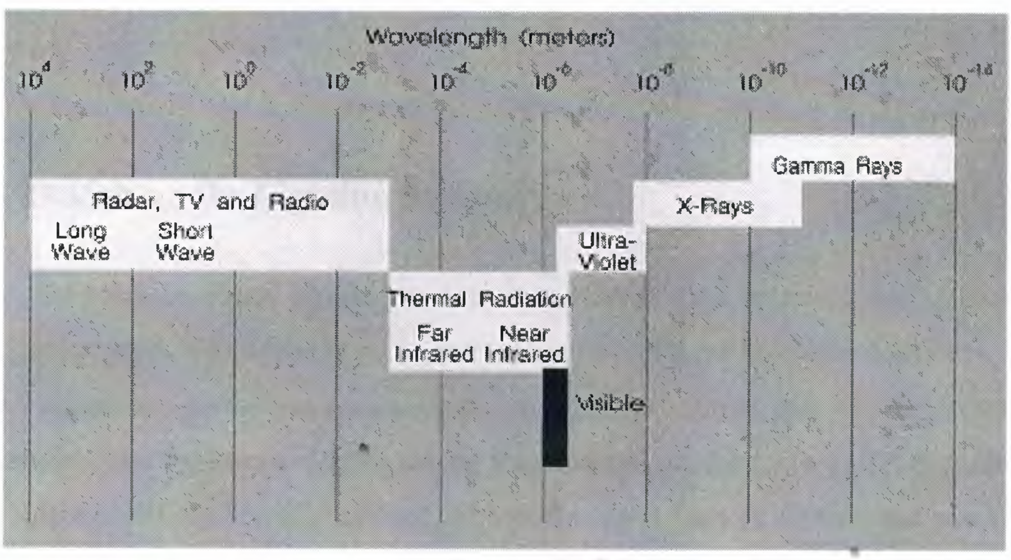

Figure 1.1: Electromagnetic field spectrums

1.2. Lighting Systems:

Light can be produced by nature or by humans. "Artificial" light is typically produced by lighting systems that transform electrical energy into light. Nearly all lighting systems do so either by passing an electrical current through an element that heats until it glows, or through gases until they become excited and produce light energy. Incandescent light sources are an example of the first method, called incandescence. Current is passed through a filament, which heats until it glows. Because this method is considered wasteful (most of the energy entering the lamp leaves it as heat instead of visible light, other light sources were pioneered that rely on the gaseous discharge method, including fluorescent, high-intensity discharge (HID) and low-pressure sodium light sources. typical lighting system is comprised of one or more of these light sources, called the lamps. Fluorescent, HID and low-pressure sodium lamps operate with ballast, a device that starts the lamp and regulates its operation. Lamps and ballasts in turn are part of the luminaries, or light fixture, which houses the system and includes other components that distribute the light in a controlled pattern.

1.3. Designing the Lighting System:

To produce a new lighting system in a construction or renovation scenario, it must be designed. The designer must determine desired light levels for tasks that are to be performed in a given space, then determine the light output that will be required to meet those objectives consistently, taking into account all the factors that degrade both light output and light levels over time. Equipment must then be chosen and placed in a layout to produce the desired light distribution. The designer must also consider a range of quality factors in his or her design choices and equipment selection, including color, minimizing glare, safety and if required, aesthetics.

1.4. Cable Insulation Materials

1.4.1. Rubber

For many years wiring cables were insulated with vulcanised natural rubber (VIR). Much cable of this type is still in service, although it is many years since it was last manufactured. Since the insulation is organic, it is subject to the normal ageing process, becoming hard and brittle. In this condition it will continue to give satisfactory service unless it is disturbed, when the rubber cracks and loses its insulating properties. It is advisable that wiring of this type which is still in service should be replaced by a more modern cable. Synthetic rubber compounds are used widely for insulation and sheathing of cables for flexible and for heavy duty applications. Many variations are possible, with conductor temperature ratings from 60°C to 180°C, as well as resistance to oil, ozone and ultra-violet radiation depending on the formulation.

1.4.2. Paper

Dry paper is an excellent insulator but loses its insulating properties if it becomes wet. Dry paper is hygroscopic, that is, it absorbs moisture from the air. It must be sealed to ensure that there is no contact with the air. Because of this, paper insulated cables are sheathed with impervious materials, lead being the most common. PILC (paper insulated lead covered) is traditionally used for heavy power work. The paper insulation is impregnated with oil or non-draining compound to improve its long-term performance. Cables of this kind need special jointing methods to ensure that the insulation remains sealed. This difficulty, as well as the weight of the cable, has led to the widespread use of p.v.c. and XLPE (thermosetting) insulated cables in place of paper insulated types.

1.4.3. P.V.C.

Polyvinyl chloride (p.v.c.) is now the most usual low voltage cable insulation. It is clean to handle and is reasonably resistant to oils and other chemicals. When p.v.c. burns, it emits dense smoke and corrosive hydrogen chloride gas. The physical characteristics of the material change with temperature: when cold it becomes hard and difficult to strip, and so BS 7671 specifies that it should not be worked at temperatures below 5°C. However a special p.v.c. is available which remains flexible at temperatures down to -20°C.

At high temperatures the material becomes soft so that conductors which are pressing on the insulation (e.g. at bends) will 'migrate' through it, sometimes moving to the edge of the insulation. Because of this property the temperature of general purpose P.V.C. must not be allowed to exceed 70°C, although versions which will operate safely at temperatures up to 85°C are also available. If p.v.c. is exposed to sunlight it may be degraded by ultra-violet radiation. If it is in contact with absorbent materials, the plasticizers may be 'leached out' making the p.v.c. hard and brittle.

1.4.4. LSF (Low smoke and fume)

Materials which have reduced smoke and corrosive gas emissions in fire compared with p.v.c. have been available for some years. They are normally used as sheathing compounds over XLPE or LSF insulation, and can give considerable safety advantages in situations where numbers of people may have to be evacuated in the event of fire.

1.4.5. Thermosetting (XLPE)

Gross-linked polyethylene (XLPE) is a thermosetting compound which has better electrical properties than p.v.c. and is therefore used for medium- and high-voltage applications. It has more resistance to deformation at higher temperatures than p.v.c., which it is gradually replacing. It is also replacing PILC in some applications. Thermosetting insulation may be used safely with conductor temperatures up to 90°C thus increasing the useful current rating, especially when ambient temperature is high. A LSF (low smoke and fume) type of thermosetting cable is available.

1.4.6. Mineral

Provided that it is kept dry, a mineral insulation such as magnesium oxide is an excellent insulator. Since it is hygroscopic (it absorbs moisture from the air) this insulation is kept sealed within a copper sheath. The resulting cable is totally fireproof and will operate at temperatures of up to 250°C. It is also entirely inorganic and thus non-ageing. These cables have small diameters compared with alternatives, great mechanical strength, are waterproof, resistant to radiation and electromagnetic pulses, are pliable and corrosion resistant. In cases where the copper sheath may corrode, the cable is used with an overall LSF covering, which reduces the temperature at which the cable may be allowed to operate. Since it is necessary to prevent the ingress of moisture, special seals are used to terminate cables.

1.5. Current Carrying Capacity of Conductors

All cables have electrical resistance, so there must be an energy loss when they carry current. This loss appears as heat and the temperature of the cable rises. As it does so, the heat it loses to its surroundings by conduction, convection and radiation also increases. The rate of heat loss is a function of the difference in temperature between the conductor and the surroundings, so as the conductor temperature rises, so does its rate of beat loss. A cable carrying a steady current, which produces a fixed heating effect, will get hotter until it reaches the balance temperature where heat input is equal to heat loss. The final temperature achieved by the cable will thus depend on the current carried, how easily heat is dissipated from the cable and the temperature of the cable surroundings.

PVC. Is probably the most usual form of insulation, and is very susceptible to damage by high temperatures. It is very important that p.v.c. insulation should not be allowed normally to exceed 70°C, so the current ratings of cables are designed to ensure that this will not happen. Some special types of p.v.c. may be used up to 85°C. A conductor temperature as high as 160°C is permissible under very short time fault conditions, on the assumption that when the fault is cleared the p.v.c. insulation will dissipate the heat without itself reaching a dangerous temperature.

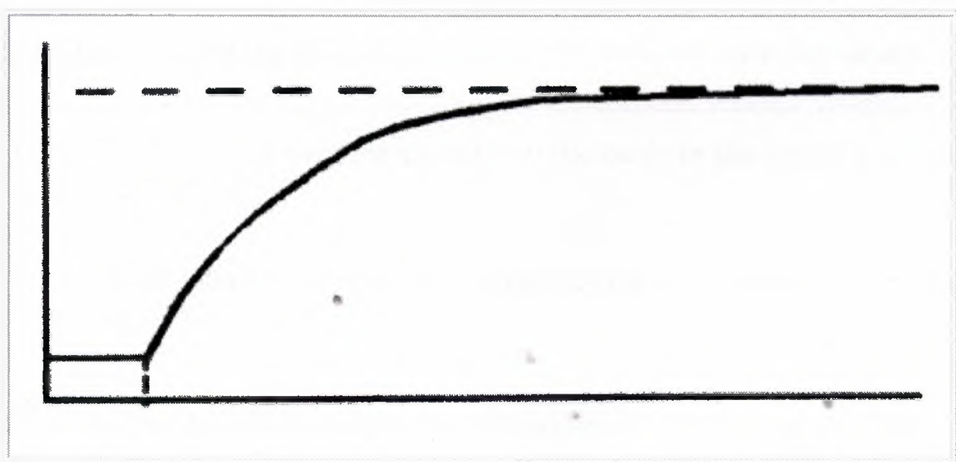

Fig1.2: Heat balance graph for a cable.

A different set of cable ratings will become necessary if the ability of a cable to shed its beat changes.

For example, if a mineral insulated cable has an overall sheath of LSF or p.v.c., the copper sheath temperature must not exceed 70°C, whilst if the copper sheath is bare and cannot be touched and is not in contact with materials which are combustible its temperature can be allowed to reach 150°C. Thus, a 1mm² light duty twin mineral insulated cable has a current rating of 18.5 A when it has an LSF or p.v.c. sheath, or 22 A if bare and not exposed to touch. It should be noticed that the cable volt drop will be higher if more current is carried.

1.6. Cable Rating Calculation

There is an increasing move away from 70°C P.V.C. insulation to materials which are more environmentally friendly, for example 90°C XLPE. The ratings of fuse gear, switches, accessories etc. are generally based upon the equipment being connected to conductors intended to be operated at a temperature not exceeding 70°C in normal service.

In view of the above it is recommended that the practice of designs based upon conductor temperatures of 70°C be regarded as the norm. In accordance with clause 512-02-01 of the Wiring Regulations the equipment manufacturer should be consulted to ascertain the reduction of nominal current rating of the equipment if conductor temperatures exceeding 70°C are used. In addition an overriding factor is often voltage drop consideration.

The Regulations indicate the following symbols for use when selecting cables:

Iz	is the current carrying capacity of the cable in the situation where it is installed
It	is the tabulated current for a single circuit at an ambient temperature of 30°C
Ib	is the design current, the actual current to be carried by the cable
In	is the rating of the protecting fuse or circuit breaker
I2	is the operating current for the fuse or circuit breaker (the current at which the fuse blows or the circuit breaker opens)
Ca	is the correction factor for ambient temperature

Cg	is the correction factor for grouping
Ci	is the correction factor for thermal insulation.

The correction factor for protection by a semi-enclosed (rewirable) fuse is not given a symbol but has a fixed value of 0.725.

Under all circumstances, the cable current carrying capacity must be equal to or greater than the circuit design current and the rating of the fuse or circuit breaker must be at least as big as the circuit design current. These requirements are common sense, because otherwise the cable would be overloaded or the fuse would blow when the load is switched an.

To ensure correct protection from overload, it is important that the protective device operating current (I2) is not bigger than 1.45 times the current carrying capacity of the cable (Iz). Additionally, the rating of the fuse or circuit breaker (In) must not be greater than the cable current carrying capacity (Iz) It is important to appreciate that the operating current of a protective device is always larger than its rated value. In the case of a back-up fuse, which is not intended to provide overload protection, neither of these requirements applies.

To select a cable for a particular application, take the following steps:

1-Calculate the expected (design) current in the circuit (Ib)

2-Choose the type and rating of protective device (fuse or circuit breaker) to be used

3-Divide the protective device rated current by the ambient temperature correction factor (Ca) if ambient temperature differs from 30°C

4-Further divide by the grouping correction factor (Cg)

5-Divide again by the thermal insulation correction factor (CI)

6-Divide by the semi-enclosed fuse factor of 0.725 where applicable

7-The result is the rated current of the cable required, which must be chosen from the appropriate tables (1.1 to 1.4).

Observe that one should divide by the correction factors, whilst in the previous subsection we were multiplying them. The difference is that here we start with the design current of the circuit and adjust it to take account of factors which will derate the cable. Thus, the current carrying capacity of the cable will be equal to or greater than the design current.

(Tables 1.1 to 1.4) give current ratings and volt drops for some of the more commonly used cables and sizes. The Tables assume that the conductors and the insulation are operating at their maximum rated temperatures.

For example if an immersion heater rated at 240 V, 3 kW is to be installed using twin with protective conductor p.v.c. insulated and sheathed cable. The circuit will be fed from a 15 A miniature circuit breaker type 2, and will be run for much of its 14 m length in a roof space which is thermally insulated with glass fiber. The roof space temperature is expected to rise to 50°C in summer, and where it leaves the consumer unit and passes through a 50 mm insulation-filled cavity, the cable will be bunched with seven others. To calculate the cross-sectional area of the required cable,

First calculate the design current Ib

$$IB = \frac{P}{U} = \frac{3000\ A}{240} = 12.5\ A$$

The ambient temperature correction factor is found to be 0.71. The group correction factor is found as 0.52. (The circuit in question is bunched with seven others, making eight in all).

The thermal insulation correction factor is already taken into account in the current rating table and need not be further considered. This is because we can assume that the cable in the roof space is in contact with the glass fibre but not enclosed by it. What we must consider is the point where the bunched cables pass through the insulated cavity, we have a factor of 0.89.

The correction factors must now be considered to see if more than one of them applies to the same part of the cable. The only place where this happens is in the insulated cavity behind the consumer unit. Factors of 0.52 (Cg) and 0.89 (CI) apply. The combined value of these (0.463), which is lower than the ambient temperature correction factor of 0.71, and will thus, be the figure to be applied. Hence the required current rating is calculated:-

$$Iz = \frac{in}{Cg \times Ci} = \frac{15\ A}{0.52 \times 0.89} = 32.4\ A$$

Table 1.1 - Current ratings and volt drops for unsheathed single core p.v.c. insulated cables								
Cross sectional area	In conduit in thermal insulation	In conduit in thermal insulation	In conduit on wall	In conduit on wall	Clipped direct	Clipped direct	Volt drop	Volt drop
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(mV/A/m)	(mV/A/m)
-	2 cables	3 or 4 cables	2 cables	3 or 4 cables	2 cables	3 or 4 cables	2 cables	3 or 4 cables
1.0	11.0	10.5	13.5	12.0	15.5	14.0	44.0	38.0
1.5	14.5	13.5	17.5	15.5	20.0	18.0	29.0	25.0
2.5	19.5	18.0	24.0	21.0	27.0	25.0	18..0	15.0
4.0	26.0	24.0	32.0	28.0	37.0	33.0	11.0	9.5
6.0	34.0	31.0	41.0	36.0	47.0	43.0	7.3	6.4
10.0	46.0	42.0	57.0	50.0	65.0	59.0	4.4	3.8
16.0	61.0	56.0	76.0	68.0	87.0	79.0	2.8	2.4

Table 1.2 - Current ratings and volt drops for sheathed multi-core p.v.c.-insulated cables								
Cross sectional area	In conduit in thermal insulation	In conduit in thermal insulation	In conduit on wall	In conduit on wall	Clipped direct	Clipped direct	Volt drop	Volt drop
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(mV/A/m)	(mV/A/m)
-	2 core	3 or 4 core	2 core	3 or 4 core	2 core	3 or 4 core	2 core	3 or 4 core
1.0	11.0	10.0	13.0	11.5	15.0	13.5	44.0	38.0
1.5	14.0	13.0	16.5	15.0	19.5	17.5	29.0	25.0
2.5	18.5	17.5	23.0	20.0	27.0	24.0	18.0	15.0
4.0	25.0	23.0	30.0	27.0	36.0	32.0	11.0	9.5
6.0	32.0	29.0	38.0	34.0	46.0	41.0	7.3	6.4
10.0	43.0	39.0	52.0	46.0	63.0	57.0	4.4	3.8
16.0	57.0	52.0	69.0	62.0	85.0	76.0	2.8	2.4

From table 1.2, 6 mm^2 p.v.c. twin with protective conductor has a current rating of 32 A. This is not quite large enough, so 10 $mm^2$with a current rating of 43 A is indicated. Not only would this add considerably to the costs, but would also result in difficulties due to terminating such a large cable in the accessories.

A more sensible option would be to look for a method of reducing the required cable size. For example, if the eight cables left the consumer unit in two bunches of four, this would result in a grouping factor of 0.65. Before applying this, we must check that the combined grouping and thermal insulation factors (0.65 x 0.89 = .0.58) are still less than the ambient temperature factor of 0.71, which is the case.

Table 1.3 - Current ratings of mineral insulated cables clipped direct						
Cross-sectional area	Volt	p.v.c. sheath 2 x single or twin	p.v.c. Sheath 3 core	p.v.c. Sheath 3 x single or twin	Bare sheath 2 x single	Bare sheath 3 x single
(mm²)		(A)	(A)	(A)	(A)	(A)
1.0	500v	18.5	16.5	16.5	22.0	21.0
1.5	500v	24.0	21.0	21.0	28.0	27.0
2.5	500v	31.0	28.0	28.0	38.0	36.0
4.0	500v	42.0	37.0	37.0	51.0	47.0
1.0	750v	20.0	17.5	17.5	24.0	24.0
1.5	750v	25.0	22.0	22.0	31.0	30.0
2.5	750v	34.0	30.0	30.0	42.0	41.0
4.0	750v	45.0	40.0	40.0	55.0	53.0
6.0	750v	57.0	51.0	51.0	70.0	67.0
10.0	750v	78.0	69.0	69.0	96.0	91.0
16.0	750v	104.0	92.0	92.0	127.0	119.0

Note that in tables 1.3 and 1.4 P.V.C. Sheath means bare and exposed to touch or having an over-all covering of p.v.c. or LSF and 'Bare' means bare and neither exposed to touch nor in contact with combustible materials.

Table 1.4 - Volt drops for mineral insulated cables				
Cross-sectional area	Single-phase p.v.c. Sheath	Single-phase bare	Three-phase p.v.c. Sheath	Three-phase bare
(mm^2)	(mV/A/m)	(mV/A/m)	(mV/A/m)	(mV/A/m)
1.0	42.0	47.0	36.0	40.0
1.5	28.0	31.0	24.0	27.0
2.5	17.0	19.0	14.0	16.0
4.0	10.0	12.0	9.1	10.0
6.0	7.0	7.8	6.0	6.8
10.0	4.2	4.7	3.6	4.1

This leads to a cable current rating of $\frac{15}{0.65 \times 0.89}$ A = 25.9 A

This is well below the rating for 6 mm² of 32 A, so a cable of this size could be selected.

1.7. Cable Voltage Drop

All cables have resistance, and when current flows in them this results in a volt drop. Hence, the voltage at the load is lower than the supply voltage by the amount of this volt drop.

Many electricians wire for no more than 5% voltage drop. This is usually fine since appliances and power tools are made to operate over a range of voltages. For a more expensive way to wire a house, you can try wiring for no more than 2% voltage drop. In this case, if you are running 20 amps, you need to up the wire size to #10 if you go more than 35 feet. In general, the percentage voltage drop decreases with a higher starting voltage.

To see this, play around with the formula for voltage drop given in terms of resistance. The resistance of various sizes of wires can be found in the CRC handbook. Practically, this means you lose less power to voltage drop if you choose a 240 volt appliance instead of a 120 volt one. And you lose a lot with low voltage lighting running on 10 or 12 volts.

The volt drop may be calculated using the basic Ohm's law formula	
U = **I** x **R**	
where	**U** is the cable volt drop (V)
	I is the circuit current (A), and
	R is the circuit resistance □(Ohms)

Unfortunately, this simple formula is seldom of use in this case, because the cable resistance under load conditions is not easy to calculate.

To calculate the volt drop for a particular cable we use tables 1.1, 1.2 and 1.4. Each current rating table has an associated volt drop column or table. For example, multicore sheathed non-armored P.V.C. insulated cables are covered by table 1.2 for current ratings, and volt drops. The exception in the Regulations to this layout is for mineral insulated cables where there are separate volt drop tables for single- and three-phase operation, which are combined here as table 1.4.

To calculate the cable volt drop:

1. Take the value from the volt drop table (mV/A/m)

2. Multiply by the actual current in the cable (NOT the current rating)

3. Multiply by the length of run in meters

4. Divide the result by one thousand (to convert mill volts to volts).

For example, if a 4 mm² p.v.c. sheathed circuit feeds a 6 kW shower and has a length of run of 16 m, we can find the volt drop thus:

From table 1.2, the volt drop figure for 4 mm² two-core cable is 11 mV/A/m.

Cable current is calculated from $I = \dfrac{P}{U} = \dfrac{6000}{240}\ \text{A} = 25\ \text{A}$

Volt drop is then $\dfrac{11 \times 25 \times 16\ \text{V}}{1000} = 4.4\ \text{V}$

Maximum acceptable volt drop specified by the IEE Regulations is 2.5% of the system

CHAPTER FOUR

ILLUMINATION AND VOLTAGE-CURRENT CALCULATIONS

4.1. Average Lighting Calculations

At working plane the luminance at the related with dimension of the room and position of the lamps with maintenance of the lamp can be calculated by

$$\phi_{Total} = \frac{A.d.E_{AV}}{\eta}$$

Where; $Ø_{total}$ = the total luminance flux

Eav = average luminance

η = utilization factor

A = the area of working place

d = dirtiness factor

$$K = \frac{a.b}{H(a+b)}$$

Where; K= Room Index,

a = the length of the working plane,

b = width of the working plane,

H = distance between lamps and working plane

H = h-(h1+h2)

h = height of the room

h1 = height of working plane

h2 = hanging distance of the lamp.

η can be found by using (Table 4.1) depending on the color of the wall, ground and ceiling and the calculated room index.

4.1.1. Lighting Calculation for kitchen Area

a= 6.4 m

b= 3.45 m

A= a x b = 22m²

H = h-(h1+h2) = 3.15-(1+0) = 2.15m

$$K = \frac{a.b}{H(a+b)}$$ = (6.4x3.45)/2.15(6.4+3.45) =1.0

Consider that the color of the Ceiling is light color (0.8), walls are light dark (0.5) and the surface is bright color (0.3).

$\eta = 0.36$

E = 250 lux (selected according to electrical installation standards for a Cooking).

d = 1.25

$$\phi_{Total} = \frac{A.d.E_{AV}}{\eta}$$ = (22x250x 1.25)/0.36= 19097.2 lumen.

$\varnothing_L$ = 2350 x 2 = 4700 lumen (selected according to electrical installation standards using 36 W fluorescent lamps).

$$n = \frac{\phi_{total}}{\phi_L}$$ = 19097.2 /4700 = 4 lamps.

4.1.2. Lighting Calculation for Restaurant Area One

a= 11.9 m

b= 11.05 m

A= a x b =131.5 m²

$$K = \frac{a.b}{H(a+b)}$$ = (11.9x11.05) / (2.3 (11.9+11.05)) =2.49

To find the value of η

Consider that the color of the Ceiling is light color (0.8), walls are light dark (0.5) and the surface is bright color (0.3).

Using linear interpolation,

Index	Efficiency	
$x_1 = 2$	$y_1 = 0.51$	
$x_2 = 2.49$	$y_2 = ?$	$y_2 = y_1 + \frac{x_2 - x_1}{x_3 - x_1}(y_3 - y_1)$
$x_3 = 2.5$	$y_3 = 0.56$	

$$y_2 = 0.51 + \frac{2.49 - 2}{2.5 - 2}(0.56 - 0.51) = 0.559$$

$\eta = 0.559$

d =1.25.

E = 75 lux (selected according to electrical installation standards for kitchens).

$\phi_{Total} = \frac{A.M.E_{AV}}{\eta}$ = (131.5x1.25x75)/0.559=22053.9 lumen

ØL = 2350 x 2 = 4700 lumen (selected according to electrical installation standards using 36 W fluorescent lamps).

$n = \frac{\phi_{total}}{\phi_L}$ =22053.9 /4700=5.3 (put 6 lamps)

4.1.3. Lighting Calculation for Restaurant Area Two

a=11 m

b=9.60 m

A=11x9.6=106 m²

$K = \frac{a.b}{H(a+b)}$ = (11x9.6)/ (2.3(11+9.6)) =2.23

Using linear interpolation,

Index	Efficiency	
$x_1 = 2$	$y_1 = 0.51$	
$x_2 = 2.23$	$y_2 = ?$	$y_2 = y_1 + \frac{x_2 - x_1}{x_3 - x_1}(y_3 - y_1)$
$x_3 = 2.5$	$y_3 = 0.56$	

$$y_2 = 0.51 + \frac{2.23 - 2}{2.5 - 2}(0.56 - 0.51) = 0.533$$

η=0.533

d=1.25

E = 75 lux (selected according to electrical installation standards for restaurant rooms).

$\phi_{Total} = \frac{A.d.E_{AV}}{\eta}$ = (106x1.25x75) / 0.533 = 18644.5 lumen

ØL = 2350 x 2 = 4700 lumen (selected according to electrical installation standards using 36 W fluorescent lamps). $n = \frac{\phi_{total}}{\phi_L}$ = (18644.5/4700) =3.9 (put 4 lamps

Table 4.1: Room efficiency

Ceiling	0.80				0.50				0.30	
Wall	0.50		0.30		0.50		0.30		0.10	0.30
Ground	0.30	0.10	0.30	0.10	0.30	0.10	0.30	0.10	0.30	0.10
$K = \frac{A \times B}{(A+B) \times H}$	Room efficiency (η)									
0.60	0.24	0.23	0.18	0.18	0.20	0.19	0.15	0.15	0.12	0.15
0.80	0.31	0.29	0.24	0.23	0.25	0.24	0.20	0.19	0.16	0.17
1.00	0.36	0.33	0.29	0.28	0.29	0.28	0.24	0.23	0.20	0.20
1.25	0.41	0.38	0.34	0.32	0.33	0.31	0.28	0.27	0.24	0.24
1.50	0.45	0.41	0.38	0.36	0.36	0.34	0.32	0.30	0.27	0.26
2.00	0.51	0.46	0.45	0.41	0.41	0.38	0.37	0.35	0.31	0.30
2.50	0.56	0.49	0.50	0.45	0.45	0.41	0.41	0.38	0.35	0.34
3.00	0.59	0.52	0.54	0.48	0.47	0.43	0.43	0.40	0.38	0.36
4.00	0.63	0.55	0.58	0.51	0.50	0.46	0.47	0.44	0.41	0.39
5.00	0.66	0.57	0.62	0.54	0.53	0.48	0.50	0.46	0.44	0.40

4.2. Voltage-Current Calculations

4.2.1. Maximum demand

Maximum demand (often referred to as MD) is the largest current normally carried by circuits, switches and protective devices; it does not include the levels of current flowing under overload or short circuit conditions, Assessment of maximum demand is sometimes straightforward. For example, the maximum demand of a 240 V single-phase 8 kW shower heater can be calculated by dividing the power (8 kW) by the voltage (240 V) to give a current of 33.3 A. This calculation assumes a power factor of unity, which is a reasonable assumption for such a purely resistive load.

There are times, however, when assessment of maximum demand is less obvious. For example, if a ring circuit feeds fifteen 13 A sockets, the maximum demand clearly should not be 15 x 13 = 195 A, if only because the circuit protection will not be rated at more than 32 A. Some 13 A sockets may feed table lamps with 60 W lamps fitted, whilst others may feed 3 kW washing machines; others again may not be loaded at all.

Lighting circuits pose a special problem when determining MD. Each lamp-holder must be assumed to carry the current required by the connected load, subject to a minimum loading of 100 W per lampholder (a demand of 0.42 A per lampholder at 240 V). Discharge lamps are particularly difficult to assess, and current cannot be calculated simply by dividing lamp power by supply voltage. The reasons for this are:

1. Control gear losses result in additional current,

2. The power factor is usually less than unity so current is greater, and

3. Chokes and other control gear usually distort the waveform of the current so that it contains harmonics which are additional to the fundamental supply current.

So long as the power factor of a discharge lighting circuit is not less than 0.85, the current demand for the circuit can be calculated from:

$$\text{current (A)} = \frac{\text{lamp power (W)} \times 1.8}{\text{supply voltage (V)}}$$

For example, the steady state current demand of a 240 V circuit supplying ten 65 W fluorescent lamps would be:

$$I = \frac{10 \times 65 \times 1.8}{240}\text{ A} = 4.88\text{A}$$

Switches for circuits feeding discharge lamps must be rated at twice the current they are required to carry, unless they have been specially constructed to withstand the severe arcing resulting from the switching of such inductive and capacitive loads.

4.2.2. Diversity

A domestic ring circuit typically feeds a large number of 13 A sockets hut is usually protected by a fuse or circuit breaker rated at 30 A or 32 A. This means that if sockets were feeding 13 A loads, more than two of them in use at the same time would overload the circuit and it would be disconnected by its protective device.

In practice, the chances of all domestic ring sockets feeding loads taking 13 A are small. Whilst there maybe a 3 kW washing machine in the kitchen, a 3 kW heater in the living room and another in the bedroom, the chance of all three being in use at the same time is remote. If they are all connected at the same time, this could be seen as a failure of the designer when assessing the installation requirements; the installation should have two ring circuits to feed the parts of the house in question.

Most sockets, then, will feed smaller loads such as table lamps, vacuum cleaner, television or audio machines and so on. The chances of all the sockets being used simultaneously is remote in the extreme provided that the number of sockets (and ring circuits) installed is large enough. The condition that only a few sockets will be in use at the same time, and that the loads they feed will be small is called diversity.

By making allowance for reasonable diversity, the number of circuits and their rating can be reduced, with a consequent financial saving, but without reducing the effectiveness of the installation. However, if diversity is over-estimated, the normal current demands will exceed the ratings of the protective devices, which will disconnect the circuits - not a welcome prospect for the user of the installation! Overheating may also result from overloading which exceeds the rating of the protective device, but does not reach its operating current in a reasonably short time. The Regulations require that circuit design should prevent the occurrence of small overloads of long duration.

The sensible application of diversity to the design of an installation calls for experience and a detailed knowledge of the intended use of the installation. Future possible increase in load should also be taken into account. Diversity relies on a number of factors which can only be properly assessed in the light of detailed knowledge of the type of installation, the industrial process concerned where this applies, and the habits and practices of the users.

4.2.3. Voltage Calculation Formula

-For three phase (220/380 v)

$$\varepsilon[\%] = \frac{100 \times L \times P}{\chi \times q \times V^2} = \frac{L \times P(KW) \times 10^5}{56 \times q \times (380)^2}$$

$$\varepsilon\% = 0.0124\frac{L\times p}{q} < 1.5$$

-For single phase (220 v)

$$\varepsilon[\%] = \frac{200\times L\times P}{\chi\times q\times V^2} = \frac{2.10^5\times L\times P(KW)}{56\times q\times (220)^2}$$

$$\varepsilon\% = 0.074\frac{L\times p}{q} < 1.5$$

Where

$\varepsilon[\%]$ = voltage calculation (percent)

P = power (KW),

L = distance of the line (m),

V = voltage (380 volt) in 3 phase and (220)in one phase .

q = conductive cross section (mm^2)

χ = conductive coefficient where χ (cu) =56 m/ $\Omega\, mm^2$, χ (Al) =35m/$\Omega\, mm^2$

4.2.4. Current Calculation Formula

-For three phase

$$I = \frac{P}{V\times COS\phi\times\sqrt{3}}$$

-For one phase

$$I = \frac{P}{V\times COS\phi}$$

Where

V = voltage (380 volt) in 3 phase and (220) in one phase.

P = power (KW),

I = current.

4.3. Cost Calculations

The cost calculations of the project are shown in table 4.2

Table 4.2: Cost calculations.

CODE*	Component	Price per piece	Quantity	Price
A-4	Duvar Globu Tesisatı:	60.00	27	1,620.00
A-3	Tavan Globu Tesisatı:	60.00	19	1,140.00
A-12.5	2x36/40 W Floresen Tesisatı:	127.00	30	3,810.00
A-14.15	Reflöktörlü 4x18/20 W Gömme Floresen Lamba tesisatı:	252.00	16	4,032.00
A-17.2	2x36/40 W W/Proff floresen lamba tesisatı:	312.00	3	936.00
				-
C-1.1	1x13 Amp. Priz tesisatı	67.00	38	2,546.00
C-1.2	2x13 Amp. Priz tesisatı.	80.00	15	1,200.00
C-2.4	Cooker Kontrol Tesisatı	146.00	2	292.00
F-5.2	Üç Faz 3X32A Priz Tesisatı	72.00	9	648.00
H-1.1	(3x4) Yollu - 3x100 Amp Bus-Bur'lı Dağıtım tablosu	735,00	3	2,205.00
H-1.4	(3x12) Yollu -3 x100 Amp Bus-Bur'lı Dağıtım tablosu	973,00	1	973.00
H-1.2	(3x6) Yollu - 3x100 Amp Bus-Bur'lı Dağıtım tablosu	799,00	1	799.00
H-4.3	MCCB 3x63 Amp.'e kadar 15kA	181,00	2	362.00
H-4.16	MCCB 4x100 Amp.'e kadar 15kA	453,00	1	453.00
H-4.15	MCCB 4x63 Amp.'e kadar 15kA	434,00	1	434.00
H-4.11	MCCB 3x250 Amp.'e kadar 25kA	567,00	1	567.00
H-4.18	MCCB 4x250 Amp.'e kadar 25kA	680,00	1	680.00
				-
H-5.8	(4x60) Amper Kollu Sigortalı Kesici Tesisatı	451.80	1	451.80
H-5.9	(4x100) Amper Kollu Sigortalı Kesici Tesisatı	706.80	1	706.80
E-2.1	Akım Otomatiği (C/O) 30/45/60 Amp.	102.00	1	102.00
				-
G-6	Merkezi Topraklama:	2,700.00	1	2,700.00
		Total Cost		26,657.60

* The code is according to EMO's list of prices.

CONCLUSION

The interior electrical installation of a production restaurant was designed in this project. Electrical installation is a very wide field and there are many ways to meet the standard installation requirements. That's why different electrical engineers can have different designs for the same project. It is in a way limited to the designer's creativity.

The best design would definitely be the one that meets the standard electrical installation requirements at the lowest cost, taking into consideration the power consumption and the decorative side of installation.

This project helps me to see conditions of jobs in business life and process of electrical project drawn in market. I think that learnt working conditions with main frame in market and in addition with taken theory education in university

NEAR EAST UNIVERSITY

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RESTAURANT ILLUMINATION

GRADUATION PROJECT
EE400

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Nicosia – 2008

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