

NED University of Engineering & Technology
Department of Electrical Engineering

LAB MANUAL
For the course

Electrical Power System Distribution (EE-359)
For T.E.(EE)

Instructor name: _____
Student name: _____
Roll no: _____ **Batch:** _____
Semester: _____ **Year:** _____

To be filled by lab technician

Attendance: Present out of ____ Lab sessions

Attendance Percentage _____

To be filled by Lab Instructor

Lab Score Sheet

Roll No.	Rubric based Lab I	Rubric based Lab II	Rubric based Lab III	Rubric based Lab IV	Rubric based Lab V	Rubric based Lab VI	OEL/PBL Rubric Score A	Final LAB Rubric Score B	Attendance Percentage C	Final weighted Score for MIS System [10(A)+10(B)+5(C)]/25 Round to next higher multiple of 5

Rubric based labs for EE-359 EPDU: 1, 3, 4 or 5, 7, 8, 10

Note: All Rubric Scores must be in the next higher multiple of 5 for correct entry in MIS system.

LAB MANUAL

For the course

Electrical Power System Distribution (EE-359)

For T.E.(EE)

Content Revision Team: Dr. Mohsin Aman, Engr. Hafiz Talha Javed Soleja

Approved By

The Board of Studies of Department of Electrical Engineering

SAFETY RULES



1. Please don't touch any live parts.
2. Never use an electrical tool in a damp place.
3. Don't carry unnecessary belongings during performance of practicals (like water bottle, bags etc).
4. Before connecting any leads/wires, make sure power is switched off.
5. In case of an emergency, push the nearby red color emergency switch of the panel or immediately call for help.
6. In case of electric fire, never put water on it as it will further worsen the condition; use the class C fire extinguisher.

Fire is a chemical reaction involving rapid oxidation (combustion) of fuel. Three basic conditions when met, fire takes place. These are fuel, oxygen & heat, absence of any one of the component will extinguish the fire.

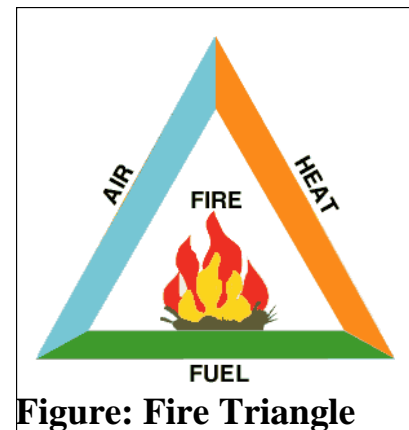
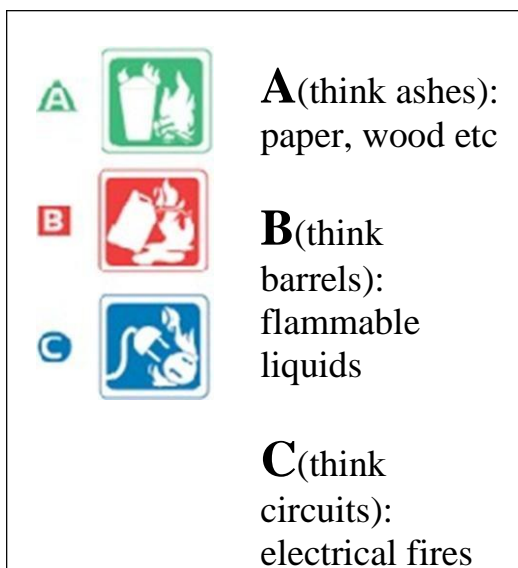


Figure: Fire Triangle



If there is a small electrical fire, be sure to use only a Class C or multipurpose (ABC) fire extinguisher, otherwise you might make the problem worsen.

The letters and symbols are explained in left figure. Easy to remember words are also shown.

Don't play with electricity, Treat electricity with respect, it deserves!

CONTENTS

Psychomotor Level: 4 CLO: [PLO (5)]				
S.No.	Date	Title of Experiment	Total Marks	Signature
1		Power Factor Improvement.		
2		Parts of power cable.		
3		Earthing.		
4		Calculating total charges in Residential, Commercial and Industrial Electricity bill.		
5		Contactor Controlled Motor Starting Circuits.		
6		Contactor Controlled Motor Circuits.		
7		Selection of Appropriate Cable Size.		
8		Illumination.		
9 (a)		Introduction to Lighting scheme design software "Dialux evo 8.1".		
9 (b)		Designing a first project on Dialux.		
10		Designing of lighting scheme for a residential building by importing AutoCAD file.		
11		OPEN ENDED LAB (Dialux Commercial building Lighting Scheme Design)		
12		OPEN ENDED LAB (Study and Analysis of distinct parts of transformers)		

LAB SESSION 01

Power Factor Improvement

OBJECTIVE

Development of connections for Power Factor Correction (PFC) of a 3-phase distribution system.

APPARATUS

- Simulator SEL-1/EV
- 3 phase supply
- Energy Analyzer
- Resistive Load Bank
- Inductive Load Bank
- Capacitive Bank

THEORY

The ratio of the actual power consumed by equipment (P) to the power supplied to equipment (S) is called the power factor.

$$PowerFactor = \cos\Phi = \frac{RealPower}{ApparentPower} = \frac{P}{S}$$

where;

$$S = \sqrt{P^2 + Q^2}$$

The power factor correction of electrical loads is a problem common to all industrial companies. Every user which utilizes electrical power to obtain work in various forms continuously asks the mains to supply a certain quantity of active power, together with reactive power. This reactive power is not transformed or used by the user, but the electricity supply company is forced to produce it, using generators, wires to carry and distribute it, through transformers and switching gears.

Power factor correction reduces the Joule losses of the transformers and the cables upstream of the installation point; reduction in losses, transmitted power being equal, is greater the lower the power factor value before applying the power factor correction.

The capacitor provides the necessary leading current (-ve Q) which results in reduce line current flowing in the system. The amount of reactive power needed is given by the following formula.

$$Q_c = P(\tan \Phi_1 - \tan \Phi_2)$$
$$C = \frac{Q}{\omega V^2}$$
$$C = \frac{P(\tan \Phi_1 - \tan \Phi_2)}{\omega V^2} \text{ where,}$$

$\tan \Phi_1$ = tan component of initial power factor

$\tan \Phi_2$ = tan component of improved power factor

PROCEDURE:

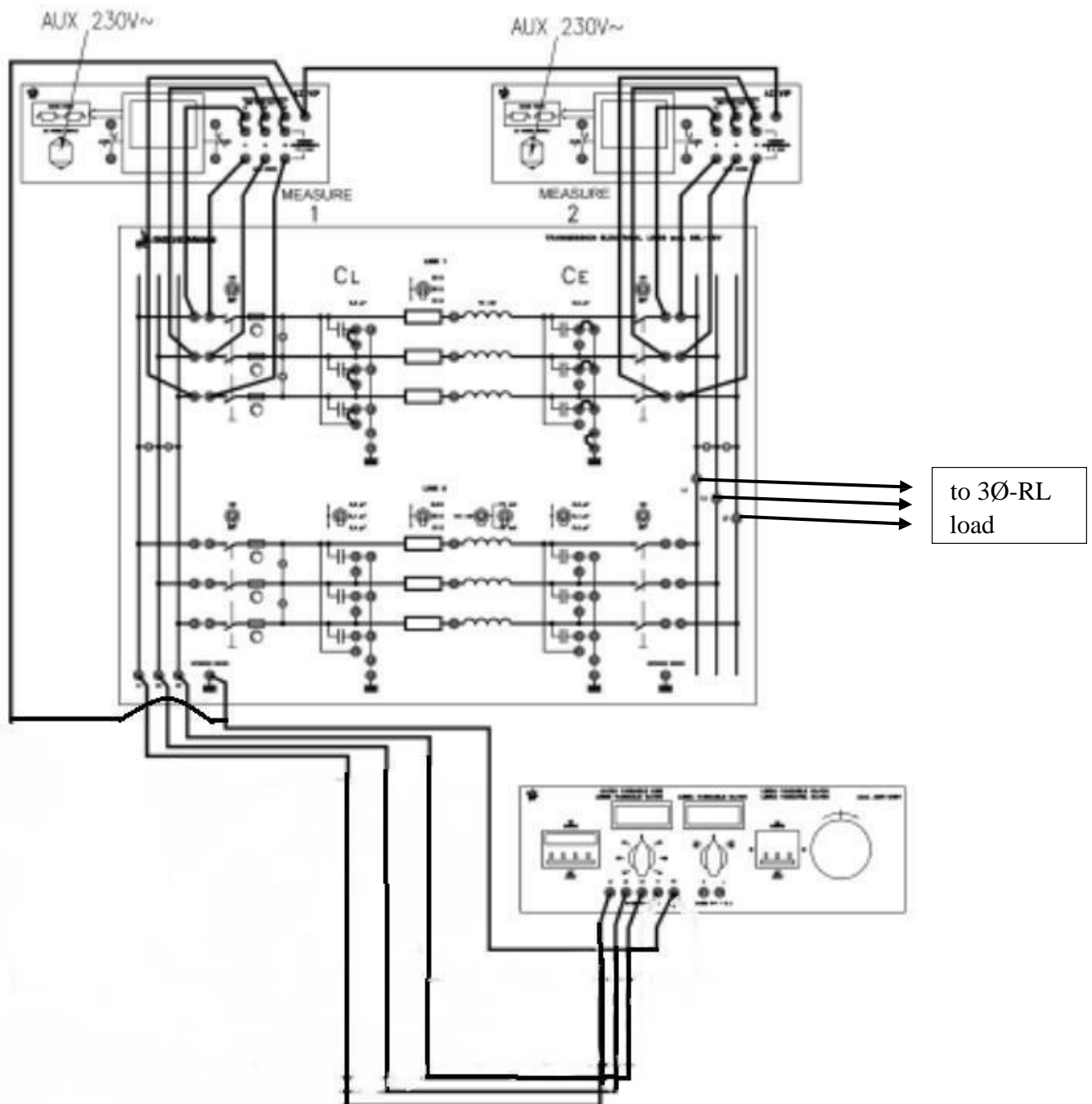


Figure 1.1 Connections of the simulator SEL-1/EV

Follow the connections shown in figure above and fill up the observation table.

OBSERVATIONS

Load Combination ($R(\Omega) + j\omega L(H)$)	Initial Power Factor	P.F Correction Using 3 x ---- μF		P.F Correction Using 3 x ---- μF	
		New Power Factor	New Line Current(A)	New Power Factor	New Line Current(A)

RESULTS / INTERPRETATIONS

TASKS

1. Draw the per-phase diagram of the system and cross-check the readings manually.
2. What is the significance of shunt and series compensation?
3. Simulate the experimental setup on Simulink.

NED University of Engineering & Technology
Department of Electrical Engineering



Course Code and Title: _____

Laboratory Session: No. _____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
Procedural Skills Displays skills to act upon sequence of steps in lab work. 15%	Not able to either learn or perform lab work procedure. 0	Able to slightly understand lab work procedure and perform lab work. 15	Able to somewhat understand lab work procedure and perform lab work. 30	Able to moderately understand lab work procedure and perform lab work. 45	Able to fully understand lab work procedure and perform lab work. 60
Response Ability to imitate the lab work on his/her own. 15%	Not able to imitate the lab work. 0	Able to slightly imitate the lab work. 15	Able to somewhat imitate the lab work. 30	Able to moderately imitate the lab work. 45	Able to fully imitate the lab work. 60
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work. 15%	Not able to use lab work observations into mathematical calculations. 0	Able to slightly use lab work observations into mathematical calculations. 15	Able to somewhat use lab work observations into mathematical calculations. 30	Able to moderately use lab work observations into mathematical calculations. 45	Able to fully use lab work observations into mathematical calculations. 60
Safety Adherence Adherence to safety procedures. 10%	Doesn't adhere to safety procedures. 0	Slightly adheres to safety procedures. 10	Somewhat adheres to safety procedures. 20	Moderately adheres to safety procedures. 30	Fully adheres to safety procedures. 40
Equipment Handling Equipment care during the use. 10%	Doesn't handle equipment with required care. 0	Rarely handles equipment with required care. 10	Occasionally handles equipment with required care 20	Often handles equipment with required care. 30	Handles equipment with required care. 40
Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

LAB SESSION 2

Power Cable

OBJECTIVE

Inspect the parts of a dissected cable and measure the size of the cable.

APPARATUS

- Dissected Cables
- SWG

THEORY

A cable is defined as an assembly of conductors and insulators used for the transfer of power in densely populated urban areas. Cables are mostly laid under the ground in order not to disturb the land beauty and to avoid using the land for power transmission purposes. A cable has the following parts;

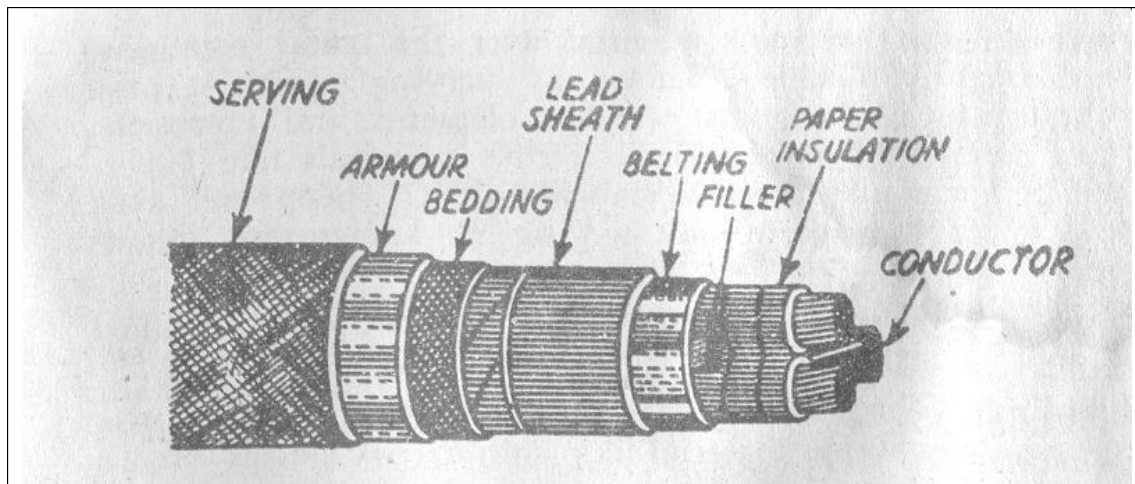


Figure 2.1: Parts of cables

Core

All cables either have a central core (conductor) or a number of cores made of strands of Copper or Aluminum conductors having highest conductivity. Conductors are stranded in order to reduce the skin effect.

Insulation

It is provided to insulate the conductors from each other and from the outside periphery. The common insulating materials are Poly Vinyl Chloride (PVC) and Polyethylene.

Metallic Sheath

Metallic Sheath protects the cable against the entry of moisture. It is made of lead, some alloy of lead or Aluminum

Bedding

In order to protect the metallic sheath from injury, bedding is wound over it. It consists of paper tape compounded with a fibrous material.

Armoring

It consists of one or two layers of galvanized steel wires or two layers of steel tape, to avoid the mechanical injury. Armoring provides mechanical strength to the cable.

Serving

A layer of fibrous material, used to protect the armoring.

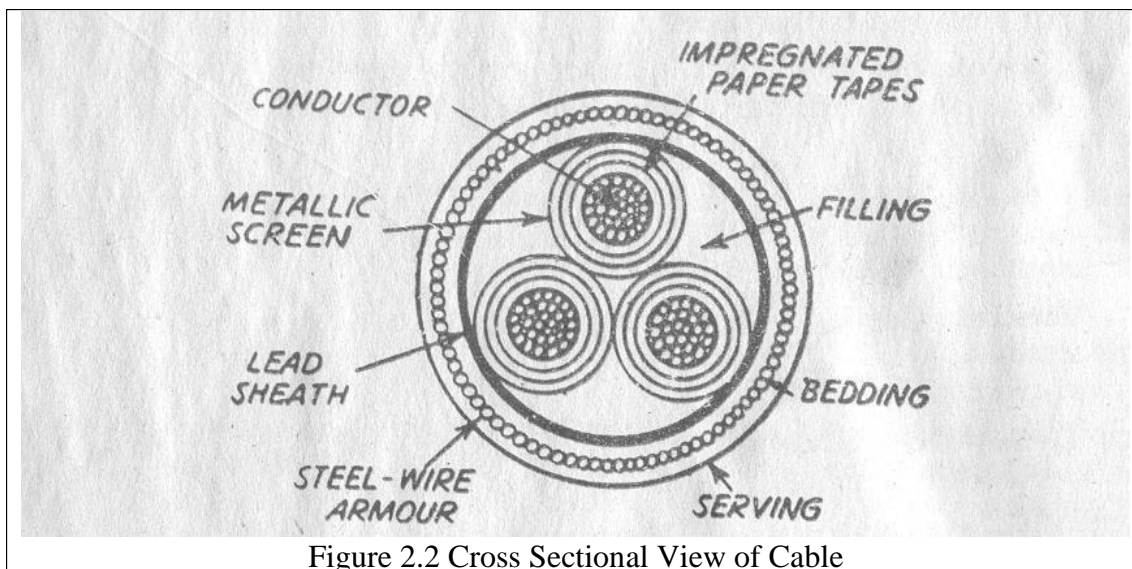


Figure 2.2 Cross Sectional View of Cable

Table 2.1 Properties of Cu and Al

S. No	Properties	Copper		Aluminum	
		Annealed	Hard Drawn	Annealed	Hard Drawn
1	Resistivity at 20°C (ohm-m $\times 10^{-8}$)	1.72	1.78 to 1.8	2.8	2.3
2	Temperature coefficient of electrical resistance at 20°C	0.00393	0.00393	0.00403	0.00403
3	Coefficient of linear expansion per unit per °C	17.0×10^{-6}	17.0×10^{-6}	23.0×10^{-6}	23.0×10^{-6}
4	Thermal conductivity W/mK	384	384	209.4	209.4
5	Density kg/m ³	8.89×10^{-3}	8.89×10^{-3}	2.71×10^{-3}	2.71×10^{-3}
6	Specific heat kJ/kg K	0.394	0.394	0.904	0.904

Measuring Units

The cross-sectional area (csa) of each gauge is an important factor for determining its current-carrying capacity. CSA can be indirectly measured by SWG or AWG as discussed below.

SWG

British Standard Wire Gauge is a set of wire sizes given by BS 3737:1964, and is generally abbreviated to SWG.(from 7/0 to 50). It is also known as: **Imperial Wire Gauge** or **British Standard Gauge**. SWG non famous but still used as a measure of thickness in guitar strings and some electrical wire. Cross sectional area in square millimetres is now the more usual in practice. Refer Fig.2.3

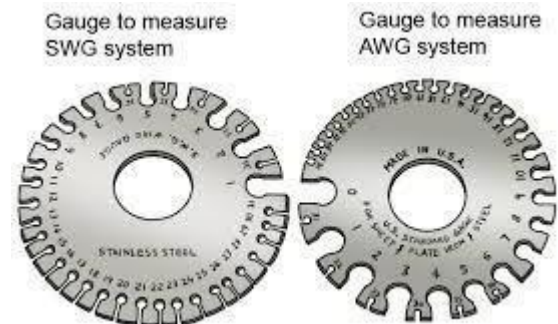


Figure 2.3 SWG vs AWG

AWG

American wire gauge (AWG), also known as the **Brown & Sharpe wire gauge**, is a logarithmic stepped standardized wire gauge system used since 1857 predominantly in North America for the diameters of round, solid, nonferrous, electrically conducting wire. Dimensions of the wires are given in ASTM standard B 258. Refer Table 2.2

Table 2.2 SWG to AWG Conversion Table

Gage No.	AWG		SWG		Gage No.	AWG		SWG	
	inches	mm	inches	mm		inches	mm	inches	mm
0	0.3249	8.25	0.324	8.23	23	0.0226	0.574	0.024	0.610
1	0.2893	7.35	0.300	7.62	24	0.0201	0.511	0.022	0.559
2	0.2576	6.54	0.276	7.01	25	0.0179	0.455	0.020	0.508
3	0.2294	5.83	0.252	6.40	26	0.0159	0.404	0.0180	0.457
4	0.2043	5.19	0.232	5.89	27	0.0142	0.61	0.0164	0.417
5	0.1819	4.62	0.212	5.38	28	0.0126	0.320	0.0148	0.376
6	0.162	4.11	0.192	4.88	29	0.0113	0.287	0.0136	0.345
7	0.1443	3.67	0.176	4.47	30	0.0100	0.254	0.0124	0.315
8	0.1285	3.26	0.160	4.06	31	0.0089	0.226	0.0116	0.295
9	0.1144	2.91	0.144	3.66	32	0.0080	0.203	0.0108	0.274
10	0.1019	2.59	0.128	3.25	33	0.0071	0.180	0.0100	0.254
11	0.0907	2.3	0.116	2.95	34	0.0063	0.160	0.0092	0.234
12	0.0808	2.05	0.104	2.64	35	0.0056	0.142	0.0084	0.213
13	0.0720	1.83	0.092	2.34	36	0.0050	0.127	0.0076	0.193
14	0.0641	1.63	0.080	2.03	37	0.0045	0.114	0.0068	0.173
15	0.0571	1.45	0.072	1.83	38	0.0040	0.102	0.0060	0.152
16	0.0508	1.29	0.064	1.63	39	0.0035	0.089	0.0052	0.132
17	0.0453	1.15	0.056	1.42	40	0.0031	0.079	0.0048	0.122
18	0.0403	1.02	0.048	1.22	41	0.0028	0.071	0.0044	0.112
19	0.0359	0.912	0.040	1.02	42	0.0025	0.064	0.0040	0.102
20	0.032	0.813	0.036	0.914	43	0.0022	0.056	0.0036	0.091
21	0.0285	0.724	0.032	0.813	44	0.0020	0.051	0.0032	0.081
22	0.0253	0.643	0.028	0.711	45	0.0018	0.046	0.0028	0.071

PROCEDURE

- Practical demonstration/inspection of different dissected cables for their parts.
- Measuring diameter and size of a cable via SWG:

$$N = \text{No. of strands in n-layers} = 1 + 3n(1+n)$$

$$D = \text{Overall Dia. of a stranded cond.} = (1+2n)d$$

where, d = dia. of each strand (SWG to mm)

- Nomenclature of cables:

129mm², 4C 37/1.83mm, XLPE/PVC/SWA/PVC

OBSERVATIONS

You are given different samples of a dissected cables of unknown cross section. Find out the following information about each of them.

Sample No.	No. of Cores	No. of Strands	Diameter of a strand (m)	Cross Sectional Area $A = \pi(d/2)^2$ (mm ²)	Nomenclature

RESULTS/INTERPRETATIONS

TASKS

1. What do you observe in different samples. List down details of each sample (with sketch / capture).
2. Give short answers to the following questions:
 - i. What will be the difference in size of Cu & Al conductor for same installation? (refer Table 2.1)
 - ii. Why do we use ACSR conductors for transmission not in distribution?

- iii. Mostly Aluminum is used in transmission system as a conductor, why not Cu as a conductor?
- iv. Differentiate between 7/44, 7/29 and 3/29 w.r.t sizes and applications?

LAB SESSION 3

Earthing

OBJECTIVE

To measure a) Soil resistivity by Wenner 4-pole method b) Earthing Resistance by 3-pole 62% method.

APPARATUS

- Digital Earth Tester MTD 20KWe
- Earthing rods
- Connecting leads
- Hammer
- Measuring Tape

THEORY

Ground or earth is a conductor that provides a **low impedance path to the earth** to prevent hazardous voltages from appearing on equipment. Earthing provides protection to personnel and equipment by ensuring total resistance of the earth path low enough to enable the operation of the protective device and isolation of the faulted circuit in the following cases.

- Insulation puncture or failure
- Breakdown of insulation between primary & secondary windings of a transformer.
- Lighting stroke



Figure 3.1 Earth Tester MTD20KWe

Earthing VS Grounding VS Bonding

Earthing is more commonly used in Britain, European and most of the commonwealth countries standards (*IEC, IS*), while **Grounding** is the word used in North American standards (*NEC, IEEE, ANSI, UL*). Earthing is to reference our electrical source to earth (*usually via connection to some kind of rod driven into the earth or some other metal that has direct contact with the earth*) while grounding of machines need to have an effective return path from the machines to the power source in order to function properly via *Neutral Circuit*. In addition, non-current-carrying metallic components in a system, such as equipment cabinets, enclosures, and structural steel, need to be electrically interconnected and earthed properly so voltage potential cannot exist between them. Fig. 3.2 shows some earthing systems.

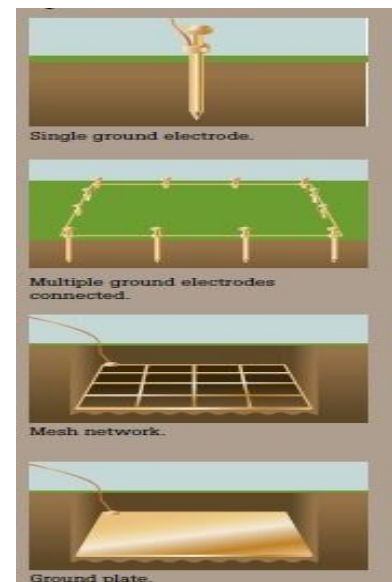


Figure 3.2 Grounding systems

Bonding is simply the *act of joining two electrical conductors together*. These may be two wires, a wire and a pipe, or these may be two Equipments. Bonding has to be done by connecting of all the metal parts that are not supposed to be carrying current during normal operations to bringing them to the same electrical potential.

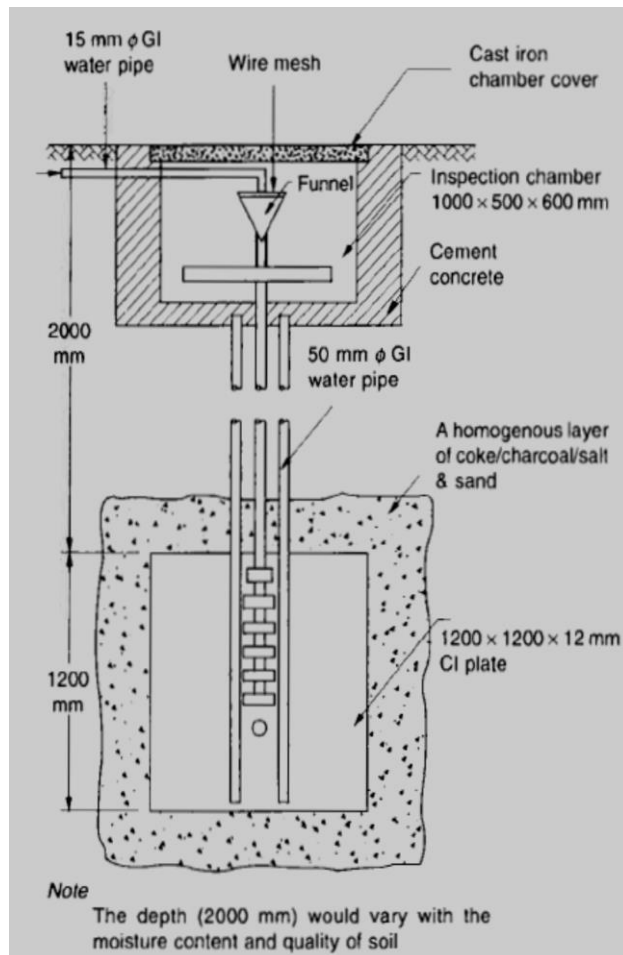


Figure 3.3 A typical layout of Plate Electrode

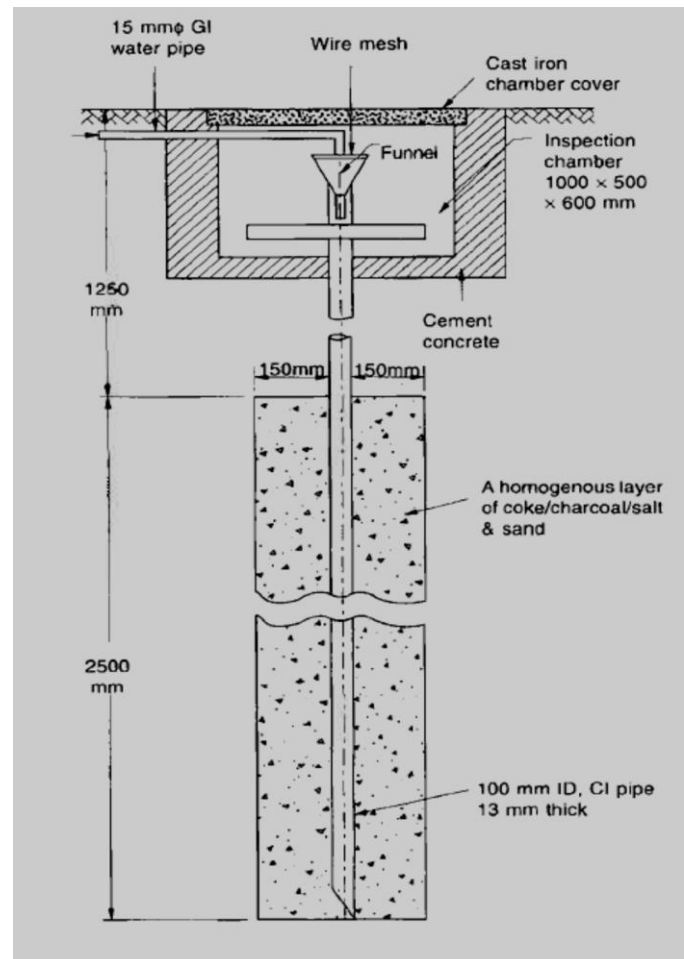


Figure 3.4 A typical of pipe electrode grounding

TYPES OF EARTH ELECTRODES

- Plate Electrodes
- Rod & Pipe Electrodes
- Strip or Round Conductor Electrodes

1. Plate Electrodes

Plate electrodes consist of copper, cast iron or steel plate (Fig.3.3). The minimum thickness of plate is recommended as;

- For cast iron - 12mm
- For GI or steel - 6.3mm
- For Copper - 3.15mm

And size not less than 600mm x 600mm.

The approximate resistance to ground in a uniform soil can be expressed by

$$R = \frac{\rho}{4} \sqrt{\frac{\pi}{2A}} \quad \text{Equation 1}$$

where,

ρ = resistivity of soil(Ω), considered uniform
 A = area (m^2) of each side of the plate

2. Rod & Pipe Electrodes

This type of earthing is more suited for a soil possessing high resistivity and the electrode is required to be longer & driven deeper into the soil to obtain a lower resistance to ground (Fig. 3.4).

The diameter, thickness and length of the pipe is recommended as follows:

- Cast iron (CI) pipes - 100mm (internal diameter), 2.5 to 3 m (long), 13mm thick.
- MS pipes - 38 to 50mm (internal diameter), 2.5 to 3 m (long), 13mm thick
- Copper - 13, 16 or 19mm diameter, 1.22 to 2.44m long.

In this case, the approximate resistance to ground in a uniform soil can be expressed by:

$$R = \frac{100}{2} \left(\frac{l}{d} - 1 \right) \quad \text{Equation 2}$$

where,

R = Resistance in Ω

l = length of pipe in cm

d = internal diameter of pipe in cm

Soil resistivity is the key factor that determines what the resistance of a grounding electrode will be, and to what depth it must be driven to obtain low ground resistance. The resistivity of the soil varies widely throughout the world and changes seasonally. Soil resistivity is determined largely by its content of electrolytes, which consist of moisture, minerals and dissolved salts. A dry soil has high resistivity if it contains no soluble salts (Table 3.1).

It has been found that the resistivity of the soil can be reduced by a chemical treatment with the following salts.

- | | |
|--|--|
| <ul style="list-style-type: none"> ▪ Normal Salt (NaCl) and a mixture of salt & soft coke. ▪ MgSO_4 ▪ CuSO_4 ▪ CaCl_2 ▪ Na_2CO_3 | <div style="border: 1px solid black; padding: 5px; display: inline-block;"> Economical and most commonly used salts </div> |
|--|--|

More common salts

Table 3.1 Resistivity of Soil

Type of Soil or Water	Typical Resistivity (Ωm)	Usual Limit (Ωm)
Sea water	2	0.1 to 10
Clay	40	8 to 70
Ground well & spring water	50	10 to 150
Clay & sand mixtures	100	4 to 300
Shale, slates, sandstone etc	120	10 to 100

Peat, loam & mud	150	5 to 250
Lake & brook water	250	100 to 400
Sand	2000	200 to 3000
Moraine gravel	3000	40 to 10000
Ridge gravel	15000	3000 to 30000
Solid granite	25000	10000 to 50000
Ice	100000	10000 to 100000

a) MEASURING THE SOIL RESISTIVITY

- 1) Wenner 4-pole method
- 2) Schlumberger method

WENNER 4 POLE METHOD PROCEDURE

Four probes are driven into the earth, at equal distances „a” apart along a straight line, at a depth „b”. The voltage between the two inner (potential) probes is measured that causes current to flow between two outer (current) electrodes to give a value of resistance R as shown Fig 3.5 and 3.6. The apparent resistivity is;

$$\rho_a = \frac{4\pi a R}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{a}{\sqrt{a^2 + b^2}}} \quad \text{Equation 3}$$

where ;

a = distance between the electrodes in meters

b = electrode depth in meters

ρ = Soil resistivity (ohm-m)

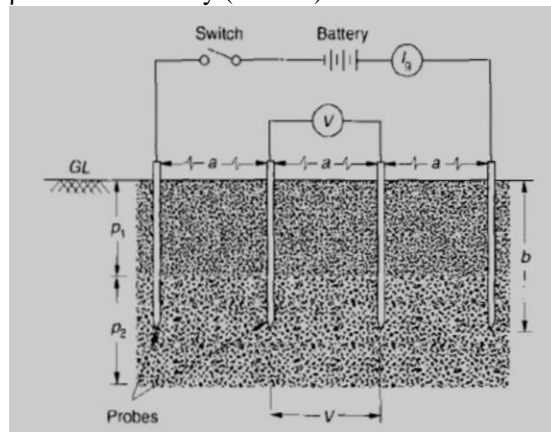
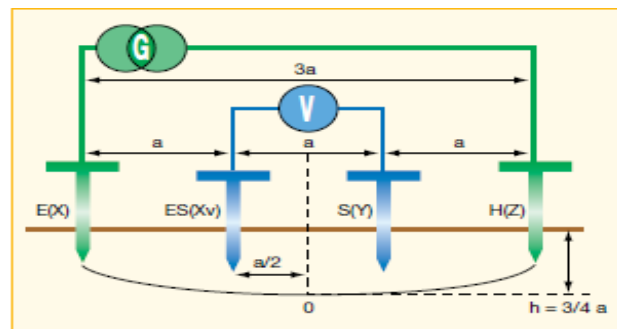


Figure 3.5 Wenner 4-pole method



Note: the terms X, Xv, Y and Z correspond to the former naming conventions used for the E, Es, S and H electrodes, respectively.

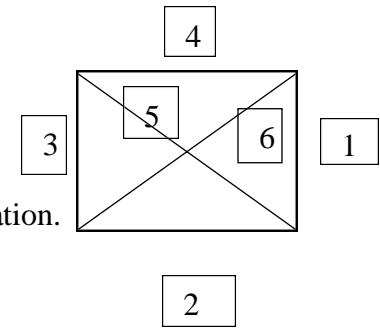
Figure 3.6 Wenner 4-pole using Earth Tester

If $b \leq \frac{a}{20}$, Eq.3 can be reduced as;

$$\rho = 2\pi a R_g \quad \text{Equation 4}$$

OBSERVATION (3a)

- Earth tester used in the lab as shown in Fig.3.1 is MTD20KWe
- Reading are traversed on the ground as shown in adjacent illustration.
- Set the selector at 4-pole.



MEASURING SOIL RESISTIVITY				
Length of Connecting Leads				
Red	(ft)	Blue	(ft)	
Green	(ft)	Black	(ft)	
Traverse 1: $1/20$ of $a =$				
Spacing Between the Rods = $a =$		(ft)	(m)	
Depth of Rods = $b =$		(ft)	(m)	
Value of Resistance Measured:		(Ω)		
Calculated Value of Resistivity(Eq. No._)				
Traverse 2:				
Spacing Between the Rods = $a =$		(ft)	(m)	
Depth of Rods = $b = 1/20$ of $a =$		(ft)	(m)	
Value of Resistance Measured=		(Ω)		
Calculated Value of Resistivity(Eq. No._)				
Traverse 3:				
Spacing Between the Rods = $S =$		(ft)	(m)	
Depth of Rods = $1/20$ of $S =$		(ft)	(m)	
Value of Resistance Measured=		(Ω)		
Calculated Value of Resistivity(Eq. No._)				
Avg. of readings:				

b) MEASURING THE GROUND RESISTANCE

- 1) 3-pole measurement method (50% rule, 62% rule)
- 2) The triangle measurement method (two stakes)
- 3) 4-pole measurement
- 4) Clamp meter measurement

MTD tester used in the lab offers ground resistance measurement via 3-pole method only.

WENNER 3-POLE METHOD (62%-Rule)

This method requires the use of two auxiliary electrodes (or "stakes") to inject the current and to provide the 0 V potential reference. The positioning of the two auxiliary electrodes in relation to the earth electrode to be measured E(X) is crucial. For correct measurement, the "0 V potential auxiliary electrode" must not be set up in the zones of influence of the earths E & H caused by the current flowing. Statistics from the field have shown that the best method for ensuring high measurement accuracy is to place stake S at a position 62 % of the distance from E on the straight line EH. Refer Fig.3.7 and Fig.3.8.

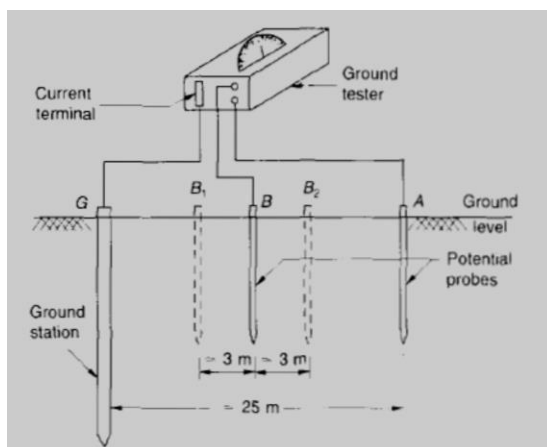


Figure 3.7 Earth R-Measurement by 3-pole method (50%)

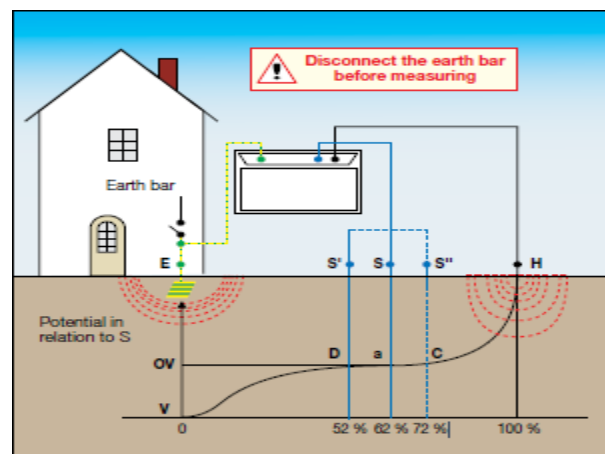


Figure 3.8 Measuring the ground resistance with the help Earth tester

Effect of Ground Electrode Size and Depth on Resistance

Size: Increasing the diameter of the rod does not materially reduce its resistance. Doubling the diameter reduces resistance by less than 10%.

Depth: As a ground rod is driven deeper into the earth, its resistance is substantially reduced. In general, doubling the rod length reduces the resistance by an additional 40%. The NEC (1987, 250-83-3) requires a minimum of 8 ft (2.4 m)

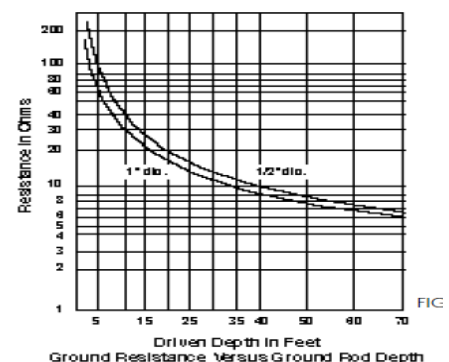


Figure 3.9 R VS depth

to be in contact with the soil. The most common is a 10 ft (3 m) cylindrical rod which meets the NEC code. A minimum diameter of 5/8 inch (1.59 cm) is required for steel rods and 1/2 inch (1.27 cm) for copper or copper clad steel (NEC 1987, 250-83-2). Minimum practical diameters for driving limitations for 10 ft (3 m) rods are:

- 1/2 inch (1.27 cm) in average soil.
- 5/8 inch (1.59 cm) in moist soil.
- 3/4 inch (1.91 cm) in hard soil or more than 10ft driving depths.

OBSERVATION (3b)

- Assume one of the rods as earth electrode (E).
- Use the procedure as above.
- Set the selector at 3-pole of the tester.

MEASURING EARTH RESISTANCE				
Length of Connecting Leads				
Red	(ft)	Blue	(ft)	
Green	(ft)	Black	(ft)	
Distance EH		(ft)		
Traverse 1 (62%D-10%):				
Depth of Rods b		(ft)		
Distance of Current(H) Electrode		(ft)		
Distance of Voltage(S) Electrode		(ft)		
Value of Resistance Measured(Eq. No.):				
Traverse 2 (62%D):				
Depth of Rods =b=		(ft)		
Distance of Current Electrode =		(ft)		
Distance of Voltage Electrode =		(ft)		
Value of Resistance Measured(Eq. No.):				
Traverse 3 (62%D+10%):				
Depth of Rods =b=		(ft)		
Distance of Current Electrode =		(ft)		
Distance of Voltage Electrode =		(ft)		
Value of Resistance Measured(Eq. No.):				

[illegible]

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Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

LAB SESSION 4**Calculating the Total Charges in a Residential, Commercial or Industrial Electricity Bill.****OBJECTIVE**

You are given a Residential, Commercial or Industrial Electricity Bill

- a. Inspect the different sections of the bill.
- b. Calculate the Electricity charges for the period as per Consumer Tariffs.

Theory**Tariff**

A way retailer charges a customer for the energy usage is tariff. It depends on;

1. Type of meter used.
2. Energy distributor.

Objectives of tariff

Since electricity is a commodity sold at a rate not to return its cost but to earn reasonable profit too with following objectives.

- (i) Recovery of cost of producing electrical energy at the power station.
- (ii) Recovery of cost on the capital investment in transmission and distribution systems.
- (iii) Recovery of cost of operation and maintenance of supply of electrical energy e.g., metering equipment, billing etc.
- (iv) A suitable profit on the capital investment.

In Pakistan, NEPRA determines electricity tariffs, keeping in view the principles of economic efficiency and service of quality, according to the prescribed tariff standards and procedure rules 1998. In most cases under long term PPAs, Generation Company's tariff is determined on cost plus basis. Distribution companies are given a multi-year performance tariff and transmission company tariff is determined on annual cost plus basis.

Types of tariffs

1. Simple tariff
2. Flat rate tariff
3. Block rate tariff
4. Time-of-use tariff
5. Two part tariff
6. Maximum demand tariff
7. Power factor tariff
8. Three part tariff

The rates of utility companies are based upon the following:

1. The amount of energy consumed [kWh]
2. The demand rate at which energy is consumed [kW]
3. Type of meter used
4. Type of utility

5. The power factor of the load.

The amount of energy consumed is measured by Energy meter shown as units billed and the demand of the system during the demand interval is measured by Demand meter comes with the feature Maximum Demand Indicator MDI.

TASKS

1. Attach the bill(s) here.
2. Attach latest NEPRA Consumer Tariff.
3. Identify different sections of the bill and terms used.
4. Verify your residential and industrial bill. Mention type of tariff used. Show proper calculations (including all taxes and payment history adjustments)
5. Show how MDI calculation is done (Block or sliding window method).
6. The industry has added an extension to its load. Assume that the load consists of atleast two motors with atleast one motor with a very poor power factor. The motor is of atleast 5 kVA.
7. Select the time of use of these loads and calculate the new units and updated bills.
8. Suggest the new load such that it leads to power factor penalty. Calculate the penalty.
9. Suggest appropriate size of capacitor for correction of power factor to 0.9.
10. If cost of capacitor is Rs. x/kVAR , calculate the payback period.
11. Develop a program on MATLAB/Arduino for billing of different consumer types as per tariffs.

RESULTS/INTERPRETATIONS

[illegible]



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Remarks					
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LAB SESSION 5**Contactor Controlled Motor Starting Circuits****OBJECTIVE**

- a) Introduction to Electrical Switching devices.
- b) Produce Contactor Control logic for three phase Induction Motor starting.

Theory**SwitchGears**

A device designed to close, open, or both, one or more electric circuits is switchgear, Figure 5.1. These include;

- a. HRC fuses
- b. Magnetic contactor
- c. Circuit Breaker (Molded Case Circuit Breaker)
- d. Load Break Switch
- e. Isolators

A fuse is an electrical safety device that operates to provide overcurrent protection of an electrical circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, thereby interrupting the current. It is a sacrificial device; once a fuse has operated it is an open circuit, and it must be replaced or rewired, depending on type. Low-voltage high rupture capacity fuses, HRC are used in the area of main distribution boards in low-voltage networks. Their features include a significantly larger construction volume compared to screw-type fuses and solid contact blades at both ends. They can therefore carry and separate larger currents. Conventional designs as high-performance fuses permit safe disconnection of residual currents up to 120 kA (rated breaking capacity), whereby the rated current can be up to 1.6 kA (rated current).

A disconnecter, disconnect switch or isolator switch is used to ensure that an electrical circuit is completely de-energized for service or maintenance. Such switches are often found in electrical distribution and industrial applications, where machinery must have its source of driving power removed for adjustment or repair. High-voltage isolation switches are used in electrical substations to allow isolation of apparatus such as circuit breakers, transformers, and transmission lines, for maintenance. The disconnecter is usually not intended for normal control of the circuit, but only for safety isolation.

Unlike load switches and circuit breakers, disconnectors lack a mechanism for suppression of electric arcs, which occurs when conductors carrying high currents are electrically interrupted

A contactor is a relay which is capable of switching large electrical loads. Contactors and relays are operated by applying a voltage to the coil of an Electro-magnet, which will cause a switch,

(or several switches) to close. The circuit that applies the voltage to the coil is referred to as the control circuit, because it controls the main device that the contactor or relay is switching.

Contactors are used to control electric motors, lighting, heating, capacitor banks, thermal evaporators, and other electrical loads.



Figure 5.1 (from left to right) HRC fuse, CB, Contactor, Isolator

Timer Delay Relay Timer:

Time delay relays, Figure 5.2, are simply control relays with a time delay built in. Their purpose is to control an event based on time. The difference between relays and time delay relays is when the output contacts open & close: on a control relay, it happens when voltage is applied and removed from the coil; on time delay relays, the contacts can open or close before or after some time delay.

Typically, time delay relays are initiated or triggered by one of two methods:

1. application of input voltage
2. opening or closing of a trigger signal

These trigger signals can be one of two designs:

1. a control switch (dry contact), i.e., limit switch, push button, float switch, etc.
2. voltage (commonly known as a power trigger)



Figure 5.2 Off-delay TDR timer

MOTOR STARTERS

Motors below 7hp is directly connected without starter because their armature resistance is very high and they have ability to afford the high current due to high resistance. So the armature winding is safe from high starting current.

But a large size of motors has a very low armature resistance. If we connect this type of motor directly to 3-phase supply then the large current will destroy the armature winding due to low resistance as there is no Back E.M.F in the motor.

Four types of starting methods are employed:

1. Star-Delta
2. Auto transformer method
3. Primary resistor starting.
4. Direct On-line.

(i) Direct Online Starters (D.O.L)

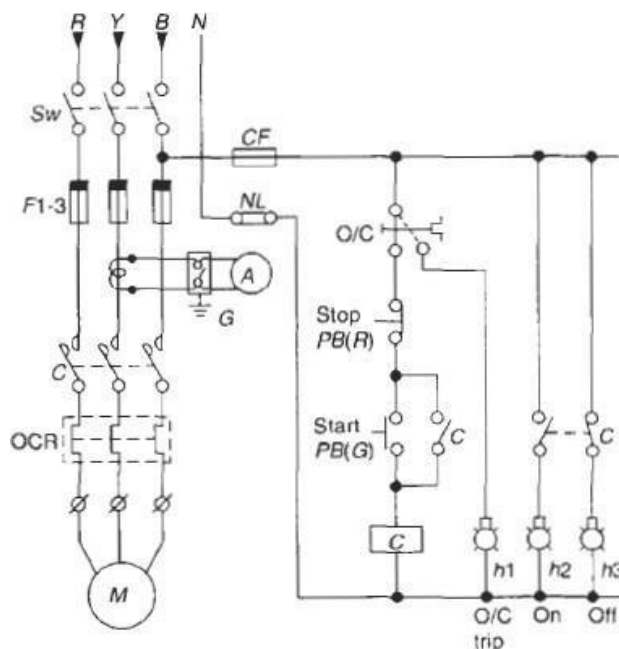
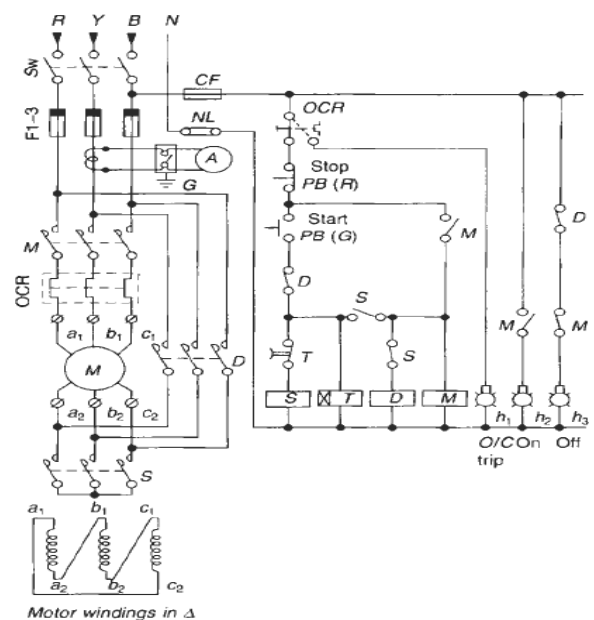


Figure 5.3 D.O.L, Y-delta starter

(ii) Star-Delta Starter



TASKS

1. Test the contactors.
2. Using Magnetic Contactor design and implement the D.O.L circuit for three phase Induction Motor. Interpret the working and control logic diagram.
3. Using Magnetic Contactors design and implement an Automatic Star-Delta Scheme for three phase Induction Motor. Interpret the working and control logic diagram.

[illegible]

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Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

LAB SESSION 6

Contactor Controlled Motor Circuits

OBJECTIVE

Produce Contactor Control Circuits for three phase Induction Motor controlling.

- a) Motor controlled from two locations (Remote control via D.O.L starting)
- b) Sequence starting of two motors manually.
- c) Sequence starting of two motors automatically with time delay.
- d) Motor operated from two alternative sources of supply.

APPARATUS

- Edibon S.A. panel (Electrical Machine Equipment EME)

Theory

The general supply of the panel is three phase 380V/50Hz at the lower part on right side as R, S, T, neutral and ground with indicating LEDs, named overall as Connection Module as shown in Fig.6.1. Apart from this, it also has 24V AC supply for circuits operating at low voltage. At the bottom of this module is a signaling lamp with a fuse that is illuminated when the sequence of the three phases is correct. If not illuminated changing the order of any two phases can modify the situation.

Activation module at top left has ON and OFF Push buttons. Contactor module at the center of the panel consisting energizing coil, power and auxiliary contacts with indicating LEDs. At the top right side is timer relay module while at the bottom left is a protection module consisting of Thermal overload relay (RTM) and Overcurrent relay or magnetothermal CB(DMT). Refer Fig.6.1-2.

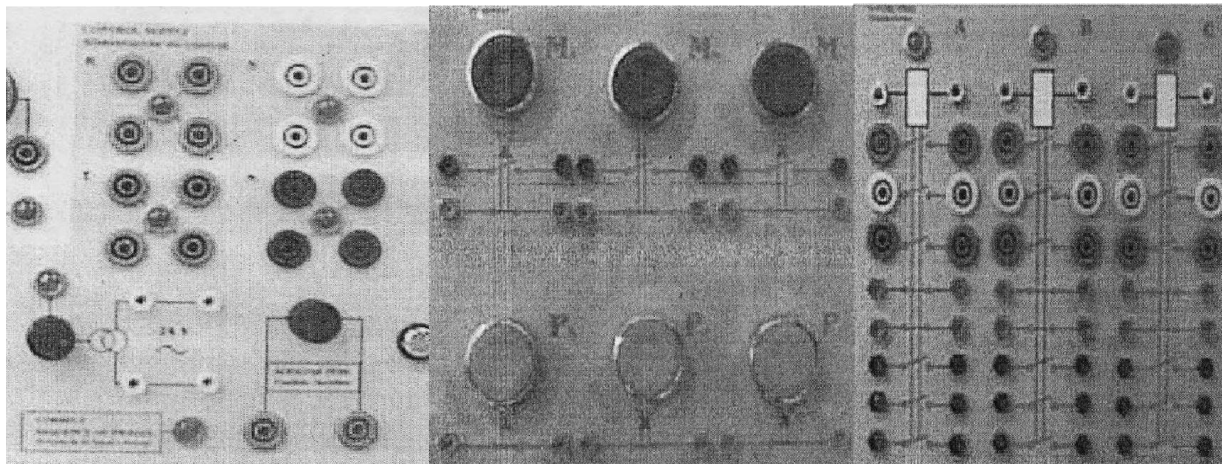


Figure 6.1 (left to right) Power supply module, Activation module and contactor module

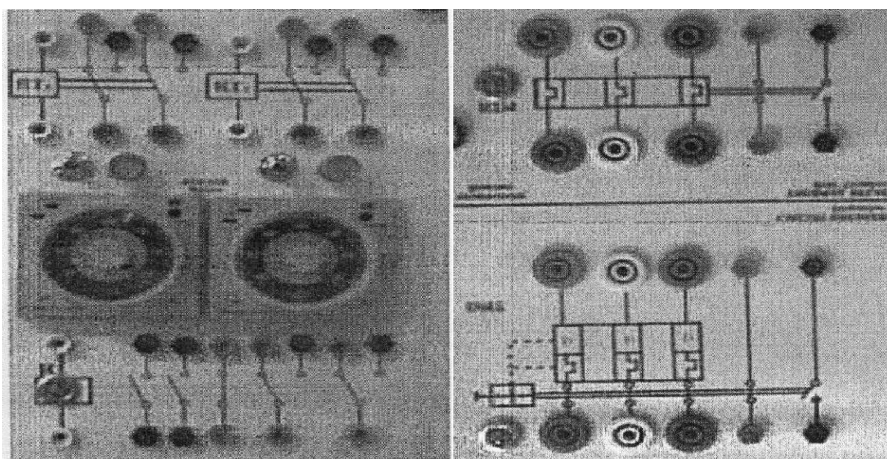
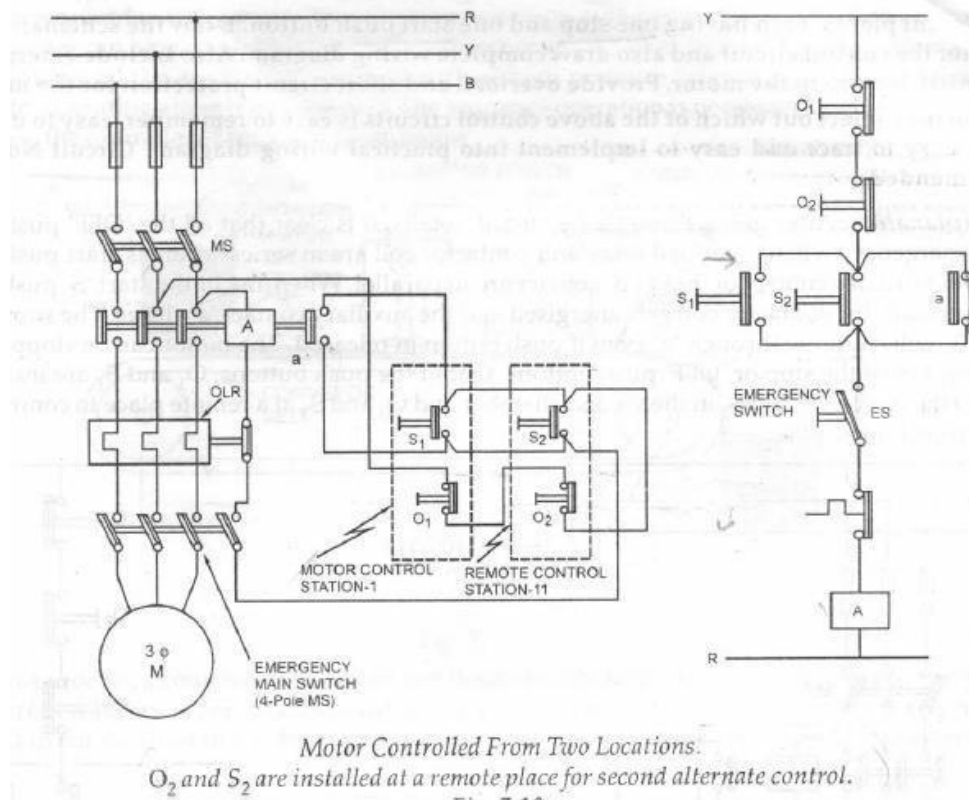


Figure 6.2 Timer relay module and protection module

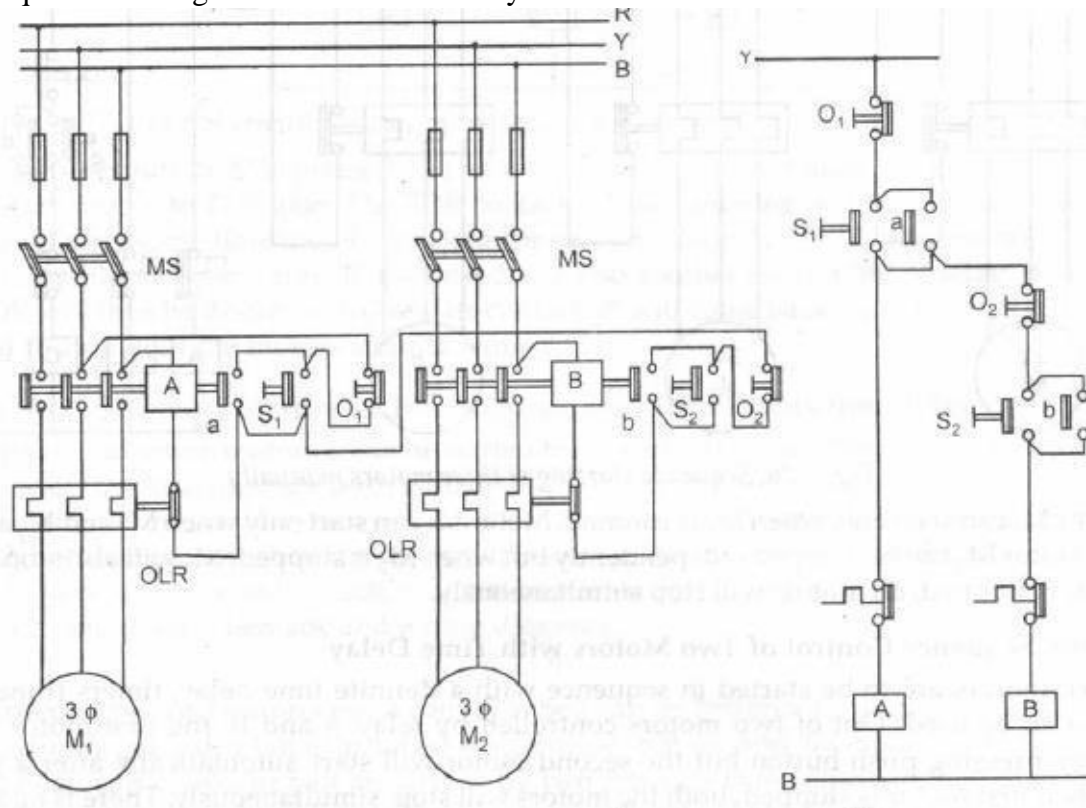
TASKS

Design and implement on the panel, the following tasks;

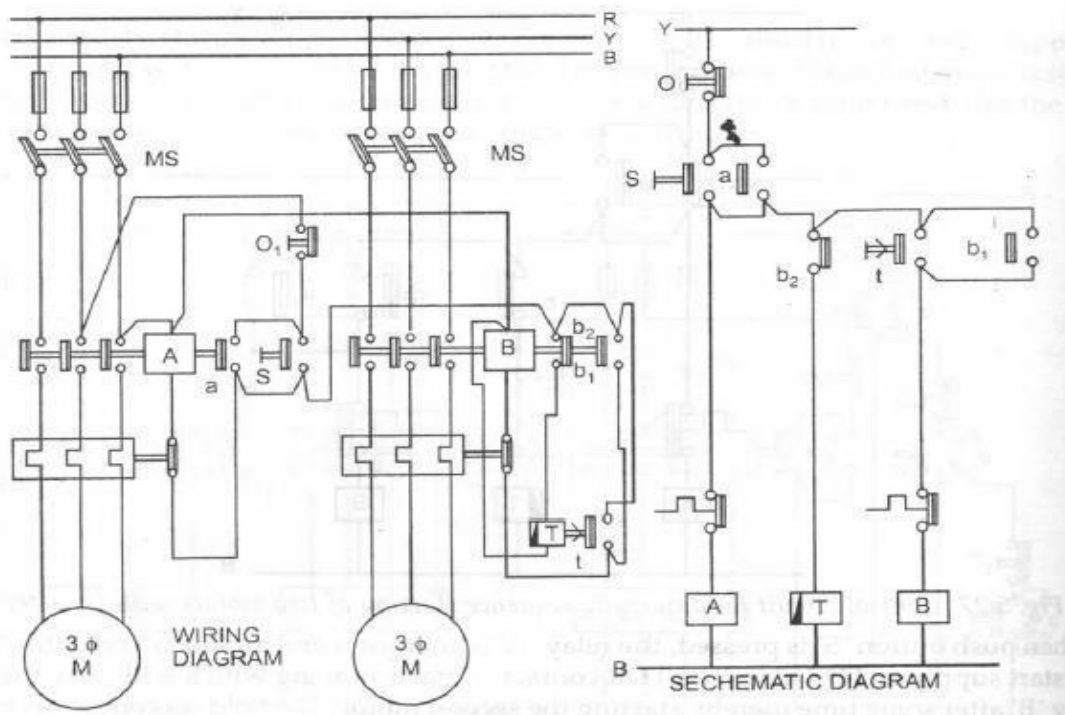
1. Motor controlled from two locations (Remote control via D.O.L starting).



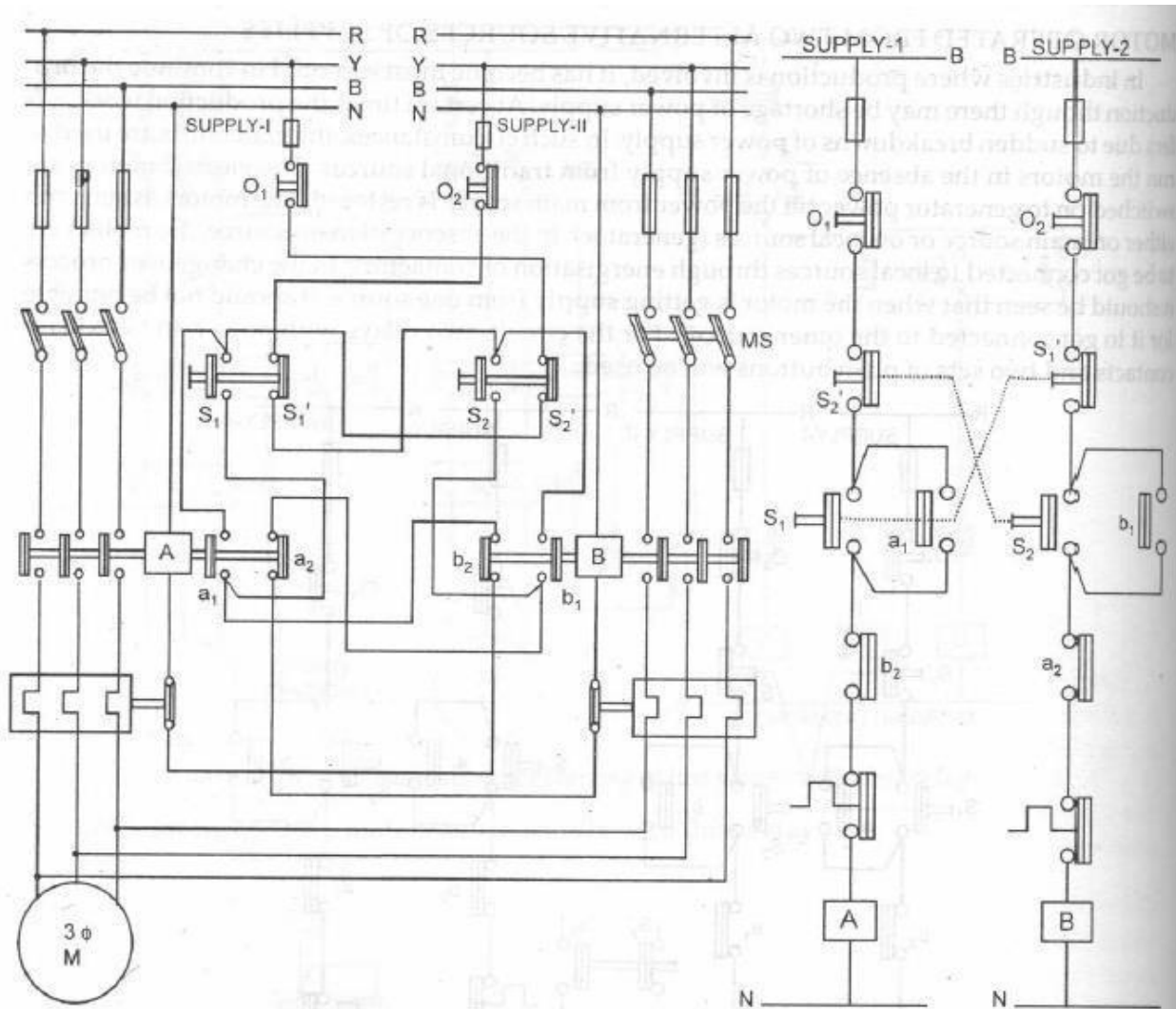
2. Sequence starting of two motors manually.



3. Sequence starting of two motors automatically with time delay.



4. Motor operated from two alternative sources of supply



RESULTS/INTERPRETATIONS

[illegible]

LAB SESSION 07**Selection of Appropriate Cable Size****OBJECTIVE**

Select the appropriate cable size for the given load.

APPARATUS

- Given Load
- Cable Tables Book

THEORY

This lab discusses the basic guidelines to determine the minimum size of cable required to satisfy a particular installation condition using Cable Table Book and national standards.

The following three main factors influence the selection of a particular cable to satisfy the circuit requirements:

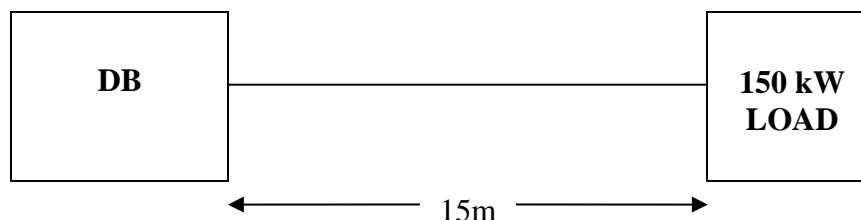
- (a) **Current-carrying capacity**—dependent upon the method of installation and the presence of external influences, such as thermal insulation, which restrict the operating temperature of the cable.
- (b) **Voltage drop**—dependent upon the impedance of the cable, the magnitude of the load current and the load power factor.
- (c) **Short-circuit temperature limit**—dependent upon energy produced during the short-circuit condition.

TASKS:

1. Determine the size of cable required & voltage drop in the cable for the following conditions.

SITUATION 1:

A 150kW, three phase load is supplying from a 400V, 50Hz supply. The circuit is protected using BSEN 60898 Type B circuit breaker and is situated 80m away from the distribution board. It is run with two other power circuits and is buried in the ground at a depth of 0.8m. There the soil resistivity is 1.2 K.m/W. The temperature within the installation can be assumed to be 30°C. Calculate the size of cable required, assume armored cable is used here.



METHOD:**STEP #01**

Determine the current requirements of the circuit. This current is known as Design current, either specified by the manufacturer or can be calculated by the formulae.

$$\text{Design Current (I}_N\text{)} = \frac{\text{kilo Watt Power}}{\text{Single Phase Voltage} \times \text{power factor}} \quad (\text{For 1 phase})$$

$$\text{Design Current (I}_N\text{)} = \frac{\text{kilo Watt Power}}{\sqrt{3} \times \text{Line Voltage} \times \text{power factor}} \quad (\text{For 3 phase})$$

If kVA power is given the above formula will change accordingly.

If motor power is given in hp then use the conversion 1hp=746 Watts.

Here,

$$\text{Design Current (I}_N\text{)} = \underline{\hspace{2cm}} = \text{Amps}$$

STEP #02

Determine the method of cable installation to be used.

Installation Conditions: The current-carrying capacity of a cable is dependent on the method of installation to maintain the temperature of the cable within its operating limits. Different methods of installation vary the rate at which the heat generated by the current flow is dissipated to the surrounding medium.

Specific conditions of installation are there like cables installed with or without wiring enclosures in air, in the ground or embedded in building materials.

STEP #03

Determine the environmental conditions in the vicinity of the cable installation, where applicable, like

- (i) the ambient air or soil temperature
- (ii) the depth of laying rating factor
- (iii) the soil thermal resistivity rating factor

Use any cable's table book to find out the correction factor values.

Here, the correction factors from the tables:

- Grouping Factor (C_g): _____
- Ambient Temperature (C_a): _____
- Soil Resistivity Factor (C_r): _____
- Depth of laying factor (C_d): _____

STEP #04

Apply the correction factors to determine the current carrying capacity (I_c) of the cable by using the formula.

$$\text{Current carrying capacity of cable} = \frac{\text{Design current}}{\text{Correction Factors}}$$

The above factors should be applied according to the design situation.

$$\text{Current carrying capacity of cable} = \frac{\text{Design current}}{C_g \times C_a \times C_r \times C_d}$$

Here,

$$\text{Current carrying capacity of cable} = \underline{\hspace{2cm}}$$

$$\text{Current carrying capacity of cable} = \underline{\hspace{2cm}}$$

$$\text{Minimum cable size} = \underline{\hspace{2cm}} \text{ mm}^2$$

Finding the Protective Device Size (I_F).

The design current should be no greater than the fuse rating. The fuse rating must be no greater than the current carrying capacity of the cable. The current carrying capacity of the cable should not be greater than the tabulated capacity of the cable i.e.

$$I_N \leq I_F \leq I_C$$

The Worst-Case Scenario

A cable may experience various different environments along its route. For example it may start at a switchboard, run through the switch room in a trench with a lid or steel flooring, pass through a duct in a wall and under a roadway, run a long way directly buried and finish on a ladder rack at the consumer. At each of these environments the thermal resistivity and ambient temperature will be different. The environment that causes the most derating of the rated current should be taken and used for the whole cable.

DETERMINATION OF VOLTAGE DROP FROM MILLI VOLTS PER AMP -METRE

According to IEEE Regulation 522-8 of the 15th edition, it is stipulated that:

The voltage drop within the installation does not exceed a value appropriate to the safe functioning of the associated equipment in normal service. For final circuits protected by an over current protective device having a normal current not exceeding 100A, this requirement is deemed to be satisfied if the drop in voltage from the origin of the circuit to any other point in the circuit does not exceed 2.5 percent of the nominal voltage at the design current, disregarding starting conditions.

The voltage drop can be determine using the following formula 50 for applications where only the route length and load current of balanced circuits are known.

$$\text{Voltage Drop (Vd)} = \frac{L \times I_N \times V_C}{1000}$$

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Remarks					
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LAB SESSION 08**Illumination****OBJECTIVE**

Verify the Inverse Square Law of illumination and compare the luminance of different types of luminous bodies.

APPARATUS

- A wooden board
- Connecting wires
- Fluorescent Light/Incandescent Light
- Other luminous sources
- LUX Meter

THEORY**INVERSE SQUARE LAW**

The inverse-square law, which states that “the illuminance at a point on a surface perpendicular to the light ray is equal to the luminous intensity of the source at that point divided by the square of the distance between the source and the point of calculation.

$$E = \frac{I}{D^2}$$

Where:

E = Illuminance in foot candles

I = Luminous intensity in candles

D= Distance in feet between the source and the point of calculation

INCANDESCENT LIGHT BULBS

Incandescent light bulbs consist of a glass enclosure (the envelope, or bulb) which is filled with an inert gas to reduce evaporation of the filament. Inside the bulb is a filament of tungsten wire, through which an electric current is passed. The current heats the filament to an extremely high temperature (typically 2000 K to 3300 K depending on the filament type, shape, size, and amount of current passed through). The heated filament emits light that approximates a continuous spectrum. The useful part of the emitted energy is visible light, but most energy is given off in the near-infrared wavelengths.



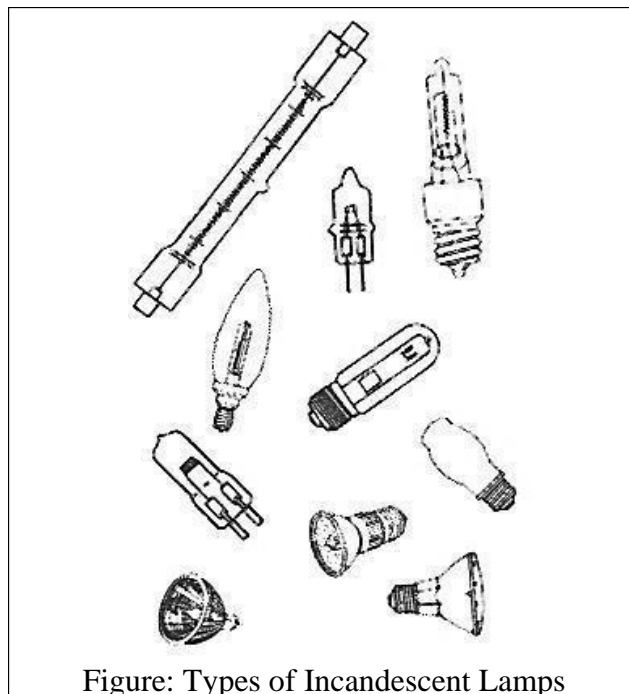


Figure: Types of Incandescent Lamps

FLUORESCENT TUBE LIGHT

A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light.

Compared with incandescent lamps, fluorescent lamps use less power for the same amount of light, generally last longer, but are bulkier, more complex, and more expensive than a comparable incandescent lamp.

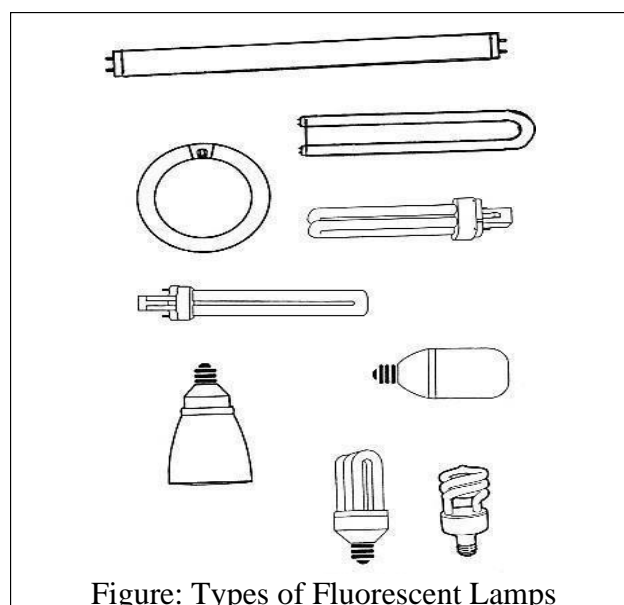


Figure: Types of Fluorescent Lamps

COMPACT FLOURESCENT LIGHTS

A compact fluorescent lamp (CFL), also known as a compact fluorescent light bulb (or less commonly as a compact fluorescent tube [CFT]), is a type of fluorescent lamp. Many CFLs are designed to replace an incandescent lamp and can fit in the existing light fixtures formerly used for incandescent.



Compared to general service incandescent lamps giving the same amount of visible light, CFLs use less power and have a longer rated life, but generally have a higher purchase price.

OBSERVATIONS

Place different lamps on the wooden board & calculate the LUX level at different point (Approx. Results only due to some unavoidable problems).

S. No.	Type of Lamp	Distance from the source	LUX
1	Incandescent		
2			
3			
1	Fluorescent Lamp		
2			
3			
1	Compact Fluorescent Lamp		
2			
3			

TASKS

1. Draw the circuit diagram of a fluorescent lamp showing fluorescent tube, ballast & starter and discuss its working.

RESULTS/INTERPRETATIONS

[illegible]



Course Code and Title: _____

Laboratory Session: No. _____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
Procedural Skills Displays skills to act upon sequence of steps in lab work. 15%	Not able to either learn or perform lab work procedure. 0	Able to slightly understand lab work procedure and perform lab work. 15	Able to somewhat understand lab work procedure and perform lab work. 30	Able to moderately understand lab work procedure and perform lab work. 45	Able to fully understand lab work procedure and perform lab work. 60
Response Ability to imitate the lab work on his/her own. 15%	Not able to imitate the lab work. 0	Able to slightly imitate the lab work. 15	Able to somewhat imitate the lab work. 30	Able to moderately imitate the lab work. 45	Able to fully imitate the lab work. 60
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work. 15%	Not able to use lab work observations into mathematical calculations. 0	Able to slightly use lab work observations into mathematical calculations. 15	Able to somewhat use lab work observations into mathematical calculations. 30	Able to moderately use lab work observations into mathematical calculations. 45	Able to fully use lab work observations into mathematical calculations. 60
Safety Adherence Adherence to safety procedures. 10%	Doesn't adhere to safety procedures. 0	Slightly adheres to safety procedures. 10	Somewhat adheres to safety procedures. 20	Moderately adheres to safety procedures. 30	Fully adheres to safety procedures. 40
Equipment Handling Equipment care during the use. 10%	Doesn't handle equipment with required care. 0	Rarely handles equipment with required care. 10	Occasionally handles equipment with required care 20	Often handles equipment with required care. 30	Handles equipment with required care. 40
Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

LAB SESSION 09(a)

Introduction to Lighting design software “Dialux evo 8.1”

OBJECTIVE

To become familiar with the environment of lighting design software “Dialux evo 8.1”

THEORY

This Lab session deals with the introduction to the main feature of lighting design software and its environment. DIAL develops DIALux - the world's leading software for planning, calculation and visualisation of indoor and outdoor lighting. All renowned luminaire manufacturers offer digital product data for planning in DIALux. The software makes professional lighting design easier and accessible to everyone. As a platform and tool, it connects planners and manufacturers all over the world. DIALux is available as a desktop version and as a basic mobile app.

System requirements

- CPU with SSE2 support
- 4 GB RAM (min. 2GB)
- OpenGL 3.3 graphics card(1 GB RAM)(for evo 4.0)
- OpenGL 3.0 graphics card(1 GB RAM)(for evo 4.1)
- Resolution min. 1024px x 768px
- Windows Vista SP2 (32bit/64bit)
- Windows 7 (32-bit/6-bit)
- Windows 8 (32-bit/64-bit)

Installation

Start the 32-bit or 64-bit setup.exe file and follow the instructions in the installation programme. To improve the software certain information is sent to DIAL during setup: - a unique ID whereby no direct inference to your person is permitted - information regarding the operating system installed (version, service pack...) - hardware information (RAM, display resolution, ...) detailed information about the capabilities of your graphics adapter.No personal data are transmitted. Parallel installation of DIALux 4 and DIALux evo on your computer is easy and causes no problems. Neither of the programmes has any influence on the other.

1. Settings

a) General Settings

Via the menu [File -> Settings -> General settings] open the mode "Settings General information Here you can define how often .DIALux evo should remind you to store your project and the maximum number of working steps that can be cancelled.

Language settings

After installation DIALux evo operates in the language of your operating system. Under "Language settings" you can change the language of the interface and the output and also switch from metric to imperial dimensions. Here it is also possible to set the display of the photometric units displayed in the European system or the imperial system.

CAD

Here you can specify how many decimal places to be displayed on dimension lines.

Project settings

Here you enter the project folder in which your projects are normally stored. Other saving locations Furniture and materials can also be stored on your hard disc. Here you can set the respective storage location. Only in extreme cases is it necessary to change the storage location.

Output settings

If desired a footer text of your own and a personal logo in the header can be displayed in the printed output. Adjust the settings here as required.

b) „Standards“ Settings

In this we can edit standard utilization profiles as per client demand and save a copy. Two standards European and Japanese are presented. However we will continue to work as per EN standards for indoor and outdoor.

With the button "Generate copy of template selected" you generate a new template which you can edit. The templates supplied by DIALux cannot be edited. You can make the following settings:

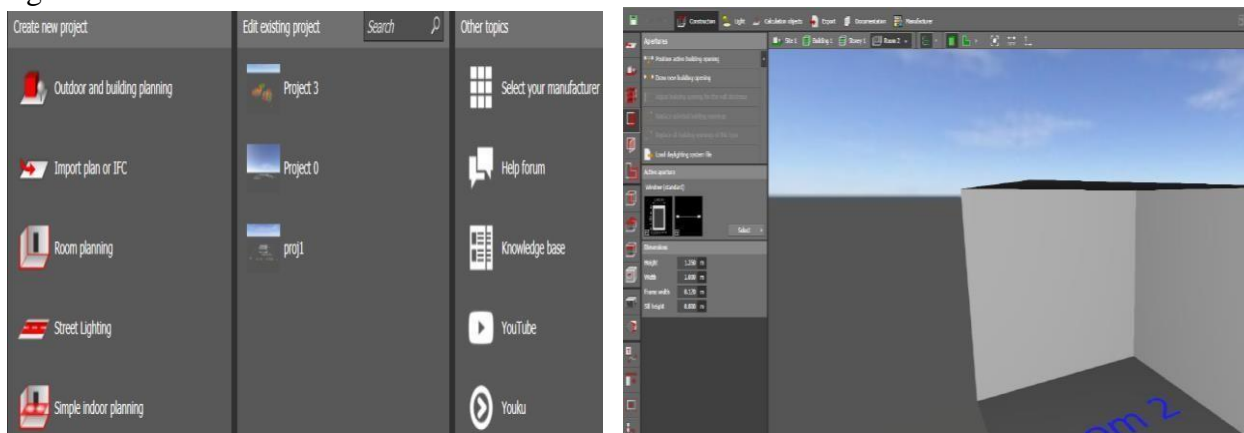
- Illuminance ratio according to LG7.
- Provision for reflection on the ceiling with emergency lighting according to LG12.
- Ratio of distance to height, SHR
- Maintenance value according to EN 12464 or blanket value.

2. Screen

The start screen is divided into three sections:

- Generate a new project
- Edit an existing project
- Other topics

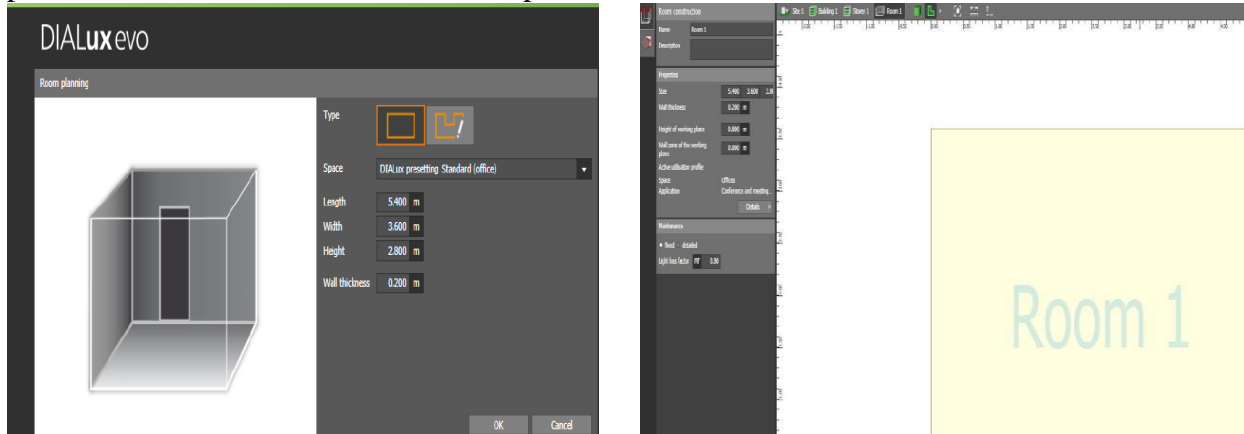
When you begin your work, you select workspace on the start screen. Later you can change between the individual workspaces within a project. To do this you use the combo box in the top right-hand corner.

**a) Outdoors and buildings planning**

To start a new lighting design project an empty plan for outdoors and buildings can be generated.

b) Room planning

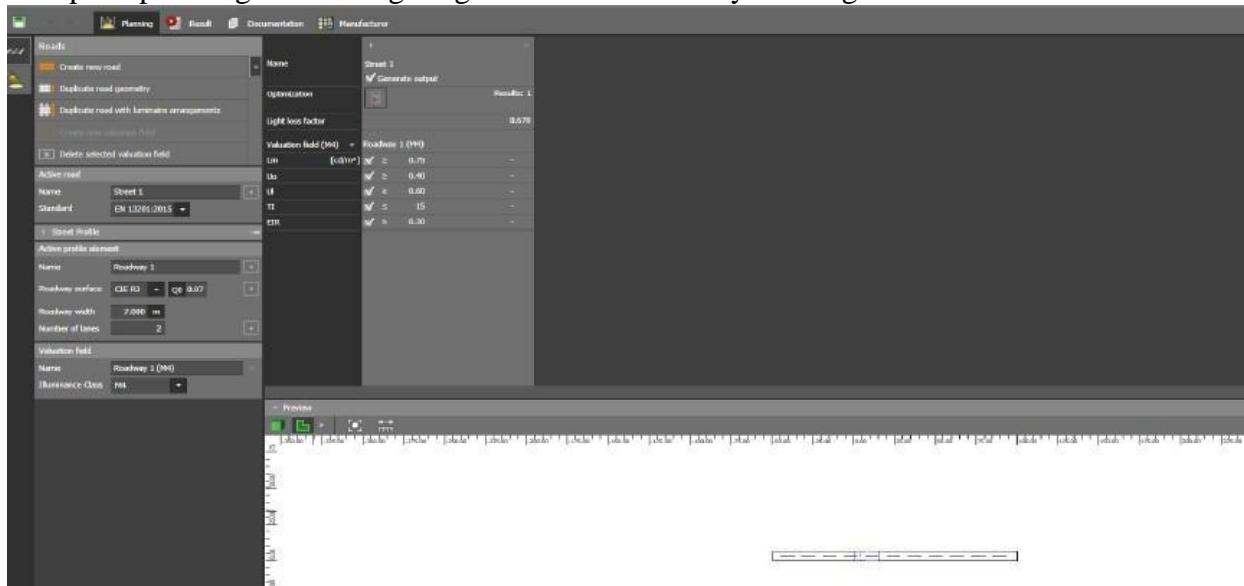
You can also start working in DIALux[®] with an "empty rectangular room". If you choose this path, room coordinates and a utilization profile can be defined.

**c) Simple Indoor Planning**

For simple indoor planning you start "evo easy". The user interface is reduced to the simplest and absolutely essential elements.

d) Street Lighting

Complete planning of street lighting can be carried out by clicking on "Street scheme editor".

**e) Import .dwg file**

If the lighting design is based on a CAD drawing (DWG/DXF), in the start screen you have the option to select "DWG/DXFImport." After importing the drawing you will be led directly to the adjustment of the DWG/DXFplan.

3. Manufacturers

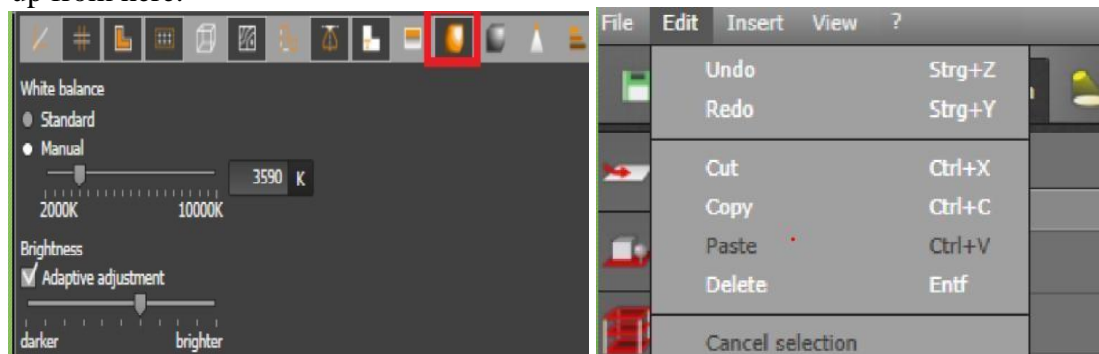
From this section of the start screen you can move directly to the selection of a manufacturer. This page lists all DIALux project partners together with electronic luminaire catalogues (online/offline).

4. Support Forum

If there are any questions or problems to do with DIALux, you can move directly from this page to our DIALuxevo and DIALux4 forum. For current issues, ideas or problems you can work within the DIALux evo board; it is not necessary to start an Internet browser first.

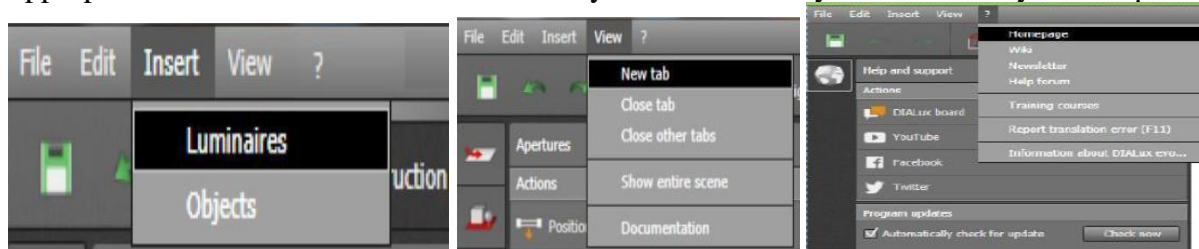
5. Menu Bar

Via the menu (file), as in other familiar Windows applications, you can load new projects and close and save existing ones. In addition you can use diverse import/export interfaces. We offer the import of STP files, DIALux4 indoor projects, luminaire data in standard formats, 3DS files and photo files. In this sub-menu, as an export medium, we support drawings such as DWG and DXF. Please note that in the installed 64-bit evo version it is not possible to import DIALux4 indoor projects. This function is at present only available in the 32-bit evo version. In the sub-menu you find all general settings options to adjust the evo interface (graphics mode, language, archive location, font etc.). The norm control centre for configuring norms and profiles can also be called up from here.



The menu [edit] supports you during the planning process with standard commands to go back several steps or to restore information. Of course it is also possible to cut, insert or delete objects (furniture, luminaires). The menu also includes an item to cancel the selection.

If you select luminaires or furniture in the menu [insert], you will be guided automatically to the appropriate tool. This function is however only available when you have already started planning.



The menu [view] enables you to open new tabs in a further viewing list directly via the CAD window. This procedure is especially helpful when you have to switch between many different views. Of course here you can also close individual tabs or all. If the CAD view is not

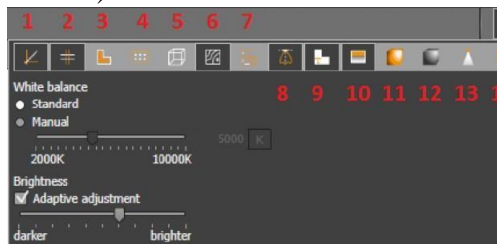
completely visible, you can display the whole scene by calling up the appropriate menu item.

You can also access the documentation mode in the view menu.

In the menu [?] helpful information with direct forwarding to the corresponding pages is hidden.

Here you will find fast and reliable support for your planning.

In DIALux evo it is possible to change the different display options by clicking top right on the "screen symbol". Display options in DIALux evo. In addition the following thirteen options (from the left) are available. You can activate or deactivate them by clicking on the respective symbol.



Display options in DIALux evo

1 Show/hide coordinates system

A green, a blue and a red help line is inserted. The red line corresponds to the x-axis, the green to the y-axis and the blue to the z-axis of the coordinate system. At the crossing of the lines is the origin of the local coordinate system. Each view, so site, building, storey and room has its own coordinate system.

2 Show/hide help lines

With the tool "guides", various help objects (circle, polyline, curve, height) are generated. These have no influence on the calculation and are a guide or as a design aid. With the option "helplines show/ hide" they can be disabled together so they do not interfere example in screenshots or views on the issue.

3 Show/hide working planes

Each room has initial a working plane. This can be shown or hidden by using this option.

4 Show/hide calculation areas

Calculation surfaces and points are used to determine photometric quantities. This can be shown or hidden by using this option.

5 Wireframe view

Surfaces of buildings and objects are usually represented with their material color or illuminated. In case of complex objects it could be helpful to hide the filled areas, so that the surface edges are shown as lines in CAD.

6 Show/hide isolines

Using the result tool results can be visualized within individual areas. There you can fade in and out and per area. With this option, all surface results are shown and hidden together.

7 Show/hide DWG drawings

With this option all DWG's used in the construction can be faded in and out.

8 Show/hide light distribution curves

This option shows or hides the light distribution curves for the selected lumiares and luminaire groups. Also, several luminaires can be selected at the same time.

9 Show/hide room designations

DIALux evo generates automatically a room name for each created room. This can be edited by the user in the assesment zones tool. Additionally reference texts and comments can be written

directly to the CAD by using the labelling tool. They may interfere in screenshots and views, so that they can be turned on and off using this option.

10 Show/hide sky textures

DIALux evo generates an artificial horizon, which is used in the CAD for better orientation. In uncalculated projects there is a blue sky day, in calculated projects a black night sky. With this option the sky texture can be faded in and out.

11 Show/hide false colours

Using this option, the calculated light textures are shown in false color. At the bottom of the screen the used colors can be set.

12 Show/hide light textures

The light texture of calculated projects can be turned on at this point and hidden.

13 Show light visualisation

With this option, the light effect of a single, selected luminaire can be directly visualized in the CAD, even if the project has not yet been calculated. Especially with spotlighting or the alignment of luminaire that is a very useful function.

14 Show energy consumption

With this option, the current energy consumption of the scene is shown at the bottom of the CAD window. Further options are in the tool "energy consumption".

6. Tools

Each mode provides different tools for the individual activities within one work step. The tools are always on the left of the display screen.

7. Activities

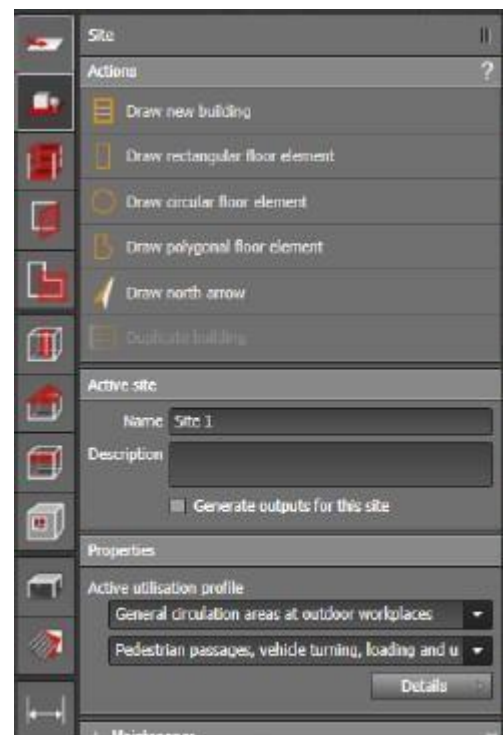
Each tool fulfils different tasks. For this you use the activities. The activities are on the right next to the tool. Settings, name and value are below the tools.

8. Site

This view shows you the whole project, the site with all buildings and objects. The description of the terrain, a suitable utilization profile, maintenance factors and the orientation of the site can be changed here.

9. Building

Focuses the view selected onto the building selected. If there are several buildings, you can select the desired building via the drop down menu. As soon as you draw more than one building, the menu appears. The numbering is in the order in which you make the drawings. Here you can give each building a name of your choice or change the positioning.



LAB SESSION 09(b)**Designing a first project on Dialux****OBJECTIVE**

Construct a plan for a building (or using CAD file) and implement general or ambient lighting scheme on Dialux.

THEORY**Drawings**

Formats supported are DXF and DWG. Imported drawings become visible or are hidden when a box is ticked.

Layer settings

Under scaling you can select the measuring unit. You can also define or change the exact position of the drawing yourself by entering the desired data under 'Positioning'. Additionally you can rotate the drawing by entering the desired rotation under 'Rotation'. Under 'Layer' you can give each layer of your drawing a different colour or hide as you wish.

Site**Draw a new building**

Before drawing a new building you can pre-set the number of floors and the total height of the building.

Drawing floor elements

With this function you can draw rectangular, circular and polygonal floor elements.

Set the north pointer

With the north pointer you quite simply indicate the compass direction by defining only two points, of which the second indicates north. The orientation of the north pointer can also be edited under 'Orientation of site'.

Duplicating buildings

This functions enables the duplication of a completed building by marking it. You define yourself which object is adopted as a duplicate. By removing the tick from the box you delete objects which you do not automatically adopt.

Controls**Active site**

Here you can give the 'active site' a new name and add a description. Additionally you can select whether any outputs should be generated for this site.

Properties

In 'Properties' you can select a user profile and define the flow of traffic. Under "Details" it is possible to change data such as maintenance values and utilization times.

Maintenance

In 'Maintenance' you can either select the maintenance interval and the contamination category according to EN 12464 or enter a fixed general maintenance factor.

Site orientation. Here you can edit the exact position (lines of latitude and longitude) with north orientation and the time zone.

Background

DWG files which have already been assigned to the project are listed here. By clicking on "Import DWG" you will have access to the "Drawing tool"[1] and can add new drawings to the project here.

Drawing new indoor room contours

After completing the design of the building the tool for 'Designing floors and buildings' opens automatically. Here you can draw indoor room contours, among other things. With the help of the scales displayed on the left and right side of the screen you can define the individual thickness of the walls. The accuracy of the scale can be set by zooming in and out. You can create new room contours by setting any number of points which you can end by clicking on the 'Close' button or via the context menu 'Close polygon'.

New empty floor level

You can set the building contours yourself for a new empty floor level. That means the floor level can be drawn larger than the one below it. While you set the individual points of the contour yourself with a right mouse click and confirming the option 'Close polygon' you can complete the contours.

Duplicating a floor level

This function enables you to duplicate a floor level which is already completed by marking it. You define yourself which objects you wish to be duplicated. By removing the tick you automatically remove objects which you do not wish to transfer.

Building apertures**Positioning and drawing building apertures**

With the aid of "active positioning of building aperture" you can insert the building aperture where the cursor is positioned with the dimensions listed under properties. With the function "Draw new building aperture" you can define the width of the building itself by defining the "Start" and "End" of the building aperture with a mouse click.

Adapting the building aperture to the thickness of the wall

With this function you adapt the depth of the door to variations in wall thickness. You do not have to replace the door with a new one but simply adapt the door already used to your project.

Exchanging selected / all building apertures of one type

With this function you can exchange one or several building apertures in one step. You select the building apertures you wish to exchange and then select "Exchange selected/all building apertures of this type". If you wish to exchange only one building aperture among many in the project, then select "Exchange selected building apertures".

If, however, you wish to exchange every single one of these building apertures which appear in the project, select "Exchange all building apertures of the same type". Then a window will open in which you can select the new building aperture. After selecting the new building aperture, this will be inserted automatically into your building.

Door / Window / Skylight Properties

Here you can change the dimensions of the building aperture. The width of the frame and the sill height of windows can also be changed and for multi-pane windows also the position and width of the uprights.

Assessment zones

If you wish to create zones within a room with different levels of illuminance, you do this under "Assessment zones". Here you can define the size and position of the respective zones within the room, allocate a distinctive name to each and define the utilization profile and maintenance data.

Room elements**Drawing room elements**

There are different options for drawing elements:

- Drawing a rectangular room element
- Drawing a circular room element
- Drawing a polygonal room element

It is not possible to use each function for drawing an element for each type of room element. For ramps and flat ceiling only the function "Rectangular room element" is available. For rectangular pillars the function "Drawing polygonal room element" is also available whereas round pillars can only be drawn by using the function "Drawing a circular room element". For steps, however, all three functions are available.

Pre-generated room elements

The ramp element is a pre-generated element which you can insert and edit. Width, length and height are adjustable which results in the inclined plane. You can however enter these directly which results in the height of the room element. The rectangular pillar is automatically adjusted to the height of the room when inserted. You can change the dimensions as desired.

The round pillar consists of at least 5 elements. The more elements used, the rounder is the effect of the pillar. When inserted this is also adjusted to the height of the room. The room element 'flat ceiling' is inserted onto the ceiling of the room in the form of an oblong solid with the standard dimensions 1 x 1 x 1 meter and can be adapted as desired.

Roofs

There are 9 roof types to choose from which you can position automatically in the building you have created.

Inserting roofs automatically

The roof is adapted to the contours of the floor level with the automatic insert function.

Drawing a roof

You can also draw any of the roof types yourself. You need only to describe the outer contours of the roof. Any inclined surfaces are calculated automatically. Dimensions and gradients can then be changed manually. After you have drawn a flat roof this can be edited by activating the context menu with a right mouse click and selecting "Edit polygon". Then, with a further right mouse click you can add another point.

Ceilings

When you have selected an active roof, you can change some of the values. As well as the ceiling height you can also change the distance to the wall, to the ceiling of the building shell and the ceiling thickness.

Inserting a ceiling in a room

With this function a suspended ceiling can also be inserted over the whole room.

Drawing a new ceiling

You can also draw the ceiling yourself and adjust its size and position as you wish.

Furniture and Objects**Drawing an arrangement**

Instead of positioning them all separately, you can also insert furniture and objects in a line arrangement. With the starting and ending point of the line arrangement you can then also edit the number, the arrangement and the alignment of the objects.

Positioning

There are different options for positioning objects.

- with "drag & drop", simply pull the object to the desired position.
- position a single object
- draw a rectangular arrangement, mark the area into which the objects should be inserted. The number, the arrangement and the alignment can be edited after marking the area.
- draw a polygonal arrangement, as for a rectangular arrangement. You can mark the area in which the objects should be placed. However, here, instead of four points, you have as many points available as you require.
- circular arrangement: by clicking onto the drawing you define the central point of the arrangement, then you pull the mouse as far back as necessary until the circle has the desired dimension. The objects are placed on the diameter, the number of objects and the radius of the circle can still be edited.

Exchanging selected / all objects of one type

This function allows you to exchange several objects at one time. If, for example, you have placed an office chair in each of the rooms in your project, by using the function "Exchange all objects of the same type" you can replace one chair by another. If you wish to exchange the chairs in one specific room only, then you mark the chairs and use the function "Exchange selected objects".

Object catalogue

In DIALux evo, as in DIALux 4, there are standard objects and an object catalogue which can be started in "Furniture and object tool" in the design mode. Objects/furniture can be added to the DIALux evo database either via "drag & drop" directly into the project or by clicking on "Adopt". By clicking on an object you can add this to your 'Favourites'. The objects used in your project are found at the top of the list. In addition the number of each object occurring in the project is displayed.

Materials**Picking materials**

If you want to know from which material the object is made or what shade of colour it is, then you can use this function. As soon as you have selected this function, the mouse cursor becomes a pipette and you only need to click on the object. The material and the shade of colour are then displayed.

Painting a material

With this function you can paint a complete surface in the desired colour. As soon as you click on "Paint material", the mouse cursor becomes a pot of paint and you can colour in the desired surface by clicking on this.

Replacing material

If you wish to replace one material or one colour by another material or colour and you wish to change many surfaces, you can simply use the function "Replace material". First you select the new material or the new colour, then click on the function "Replace material" and then in your project click on the material or colour which is to be replaced.

Creating coloured material

If the colours available in DIALux are not exactly what you are looking for, then you can create a material in your own colour.

Creating texture

Here you can import and edit your own textures. As well as the size of the texture you can also import the type of material and the degree of reflectance. You can import *.jpg, *.png und *.bmp files.

Colour catalogue

In the colour catalogue there is a list of pre-defined colours which you can add to your DIALux evo database via the button "Adopt".

Material catalogue

In the material catalogue there are many pre-defined materials of different kinds. Here you will find examples of textures for roof tiles, floor and wall coverings or for windows and doors.

Dimensions**Drawing dimensioning lines**

In order to enter the dimensions of your project into the drawing, you can draw dimensioning lines and adapt these as required. Position the starting and ending points with the help of the manipulator. You can then change the type and appearance of the dimensions under the format function.

Labelling

With the labelling tool you can enter texts into your projects. After you have defined the text and the position, you can still change colour, alignment, emphasis and font size.

Help lines

Working with help lines. Help lines are freely positionable objects on which objects (luminaires, furniture, calculation objects, points of the room, points of extrusion bodies or points of calculation surfaces) can be positioned and then aligned.

Copying and arranging

The "copy and arrange" tool allows you to copy, group, combine and align objects and arrangements. Copy along a line, in a circular mode, polygonally or along a winding line. Select one or more objects and press on the desired type of multiple copy. Click on the starting and ending point of the line along which you would like to insert the objects or indicate the required polygonal points or the radius with the aid of the mouse.

Views

Here you can generate images of your projects from many perspectives and save them.

Project overview

In the project overview you can see all the objects used in the project, listed according to building, floor level and room. If you click on an element in the overview, this will be marked in the drawing.

Luminaires

After finishing your plan, in the luminaire mode you can now, in the next step, plan the lighting. The first control function "Activities" lists all the options for inserting luminaires.

- Draw a rectangular arrangement
- Draw a polygonal arrangement
- Draw a circular arrangement
- Draw a linear arrangement
- Position a single luminaire
- Automatic arrangement for defined areas

You can position luminaires directly in your project using the "drag & drop" function. If you do not wish to use the luminaires which have been inserted, you can simply replace them by selecting the function "Exchange selected luminaires" or "Exchange all luminaires of this type". To do this mark the appropriate luminaires in the CAD view. Just use the import function "Import luminaire file". In the control function "Active luminaire" the luminaire with which you last worked is displayed. With the "Select" button you come to the history of the luminaire. If luminaires have already been used, a list of the luminaires which were last used will be shown. Clicking with the right mouse button on a luminaire image will open the appropriate context menu. Here the data sheet of the luminaire can be displayed, if required, or the luminaire itself can be marked as a favourite or it can be deleted from the history. The data sheet of the luminaire can also be shown in the luminaire comparison. An external window, independent of evo, is opened. Here you have the opportunity to have an overview of a comparison of a large number of luminaires. The next tab "Catalogues" leads you to the luminaire catalogues which have been installed. You can also call up our project partners via "further catalogue". If you mark a luminaire in CAD, then other details will be shown as well as the photometric data. You require these details in particular when you wish to manually adjust the position, the assembly, the photometric values of the luminaire, maintenance data or even energy consumption.

Luminaire folders

Here you can access not only history, favourites and catalogues but also the folders which you have generated for luminaires. You can generate and define these folders yourself and then import them into evo by clicking on "Add folder...". After you have added a folder, you can open it in a separate window with a double click. On the left hand side all the sub-folders are listed which you can select individually. The same principle is found in the "Furniture and object tool".

Lamps

The lamp tool provides support when modifying an active luminaire. If you have not selected a luminaire in the CAD view, then an explanatory text appears below the control. As soon as a luminaire is marked, the complete control field opens. Here you can adjust not only the luminous flux but also the power and colour temperature of the original fitting and also the spectrum. In addition it is also possible to change the type of lamp. A list of the usual alternatives is available in the drop down menu. After adjusting manually you only need to click on the button "Adopt" and the new fitting will be included in your planning.

Editing joints

If the luminaire model being used has one or more joints, then this is indicated by a symbol next to the manufacturer's logo. The editing of the joints in accordance with their possible alignment is done either graphically in the CAD view or manually in the input box.

Filters

With the filter tool you can furnish your luminaire with different colour filters, correction or other filters. To do this, select one or more luminaires with the mouse and select the filter desired either from those last used, from your favourites or from the DIAL filter catalogue. The tool shows you

the filter spectrum and the spectrum resulting from the filter spectrum and the lamp spectrum. With the 'slider' you can determine how large the area should be which is covered by the filter. The RA value can be seen below the resulting spectrum. Values from R1 to R14 fade in when you move the mouse over the comparison colours. Here you can remove a colour filter which has been inserted or adopt the current selection.

Lighting scenes

You can create as many lighting scenes as you wish for your projects. In each scene you can use different luminaires or different settings of the luminaires for the lighting installation. DIALux calculates automatically how the luminaires should be distributed so that there are no conflicts between the lighting scenes due to contradictory dimmer setting. The first lighting scene is set automatically for you. If you do not make any changes to this, all luminaires will be calculated with 100% luminous flux in one single lighting scene.

Generating a lighting scene for one zone

Using this function, with one click you can generate a lighting scene in which only those luminaires are used in the selected room or zone in order, for example to achieve a calculation result for one room only without the influence from external light sources. No other luminaires in this lighting scene are taken into consideration.

Duplicating lighting scenes

With this function you can generate new lighting scenes. An already existing lighting scene which has been generated automatically by DIALux is used as the basis. Changes can be made to the copy, e.g. different dimmer settings or different compositions of luminaire groups.

Generating new luminaire groups

Luminaire groups are luminaires which are switched on and off or are dimmed together or which have common channel settings. Just mark the luminaires concerned and press "Generate new luminaire group".

Active lighting scene

Here you can edit the name and description of the lighting scene. For larger projects it is of great benefit to allocate names to the lighting scenes, e.g. "all on", "presentation", "pause", etc.

Lighting scenes

All the lighting scenes created are listed here. They can be called up with a double click. Alternatively you can rearrange the lighting scenes at the top of the window and activate them with the button next to them. The creation of lighting textures for CAD may take a few moments. Room lighting scenes are marked with (S). New luminaires are always inserted first into the active lighting scene. Here it is possible to combine lighting scenes which makes sense e.g. for room lighting scenes. Instead of generating three room lighting scenes and all the combinations of the different lighting scenes, you now need only the three room lighting scenes.

With multi-channel luminaires each channel can be set separately. On the right hand side you can see the symbols for:

- updating each of the lighting scenes.
- setting all the luminaires together to 100% luminous flux.
- setting all together to 0%.
- combining luminaire groups with the same dimming values into one new luminaire group.

Energy consumption

In the course of your planning you acquire an overview of how high the current energy consumption of your installation is or how much energy can be saved. To do this select the option "Display energy tachometer" in [Light-> Properties tachometer] or select the appropriate option in display options. In addition you can set whether the LENI(kWh/a/m²) value, the energy consumption (kWh/a) or the costs should be displayed in the tachometer.

Start Calculation

With the evo 4, the calculation tool was removed from its mode and integrated into the header. This makes it possible to start the calculation at any time, regardless of the current view and recently performed steps. While calculating the button changes from "Start calculation" to "Cancel calculation" With the second button you can discard the results.

Calculation objects

Here you can position additional calculation objects and set their calculation parameters. You can position the new calculation object in the scene using the mouse and "drag & drop" or you can draw it as a rectangular or polygonal object directly in the scene. You can define the type of calculation object as usual via "Select". The following options are available for calculation areas:

- perpendicular illuminance adaptive. • vertical illuminance • UGR (Unified Glare Rating)
- GR (Glare Rating) • cylindrical illuminance • semi-cylindrical illuminance
- hemispheric illuminance • camera-oriented illuminance. • Daylight quotient/ratio
- free calculation direction

For calculation points the parameters are:

- horizontal illuminance • vertical illuminance • UGR (Unified Glare Rating)
- GR (Glare Rating) • cylindrical illuminance • semi-cylindrical illuminance
- hemispheric illuminance • daylight quotient/ratio • free calculation direction

Visual task areas

With this tool it is possible to set the visual task area in which the current visual task is carried out according to DIN EN-12464-1. Draw the task area as a rectangle or polygon in your CAD window. The surrounding area prescribed by the norm and the background area are generated automatically, can however be edited and adjusted later.

Areas of activity

According to DIN EN 12464 - 1, in areas in which activities are carried out, the median cylindrical illuminance has to be checked in order to guarantee good visual communication and easy recognition of objects. The height for this test is 1.2 m for persons sitting and 1.6m for persons standing. You can find the results in the result tool or in the documentation under "Summary of results EN 12464".

Room main surfaces

DIN EN 12464 requires that the illuminance on the main surfaces within closed areas is checked. This can be achieved with this tool. We recommend automatic positioning for empty rooms. If furniture or obstructions conceal the walls, it is better to create the main surfaces manually. Draw the contours of the relevant area as a rectangle or a polygon. DIALux generates suitable calculation objects automatically. The easiest method is to construct the main room surfaces in a 2D view.

Results**Result tool**

With the result tool you can check the values determined by the calculation. You can use a traffic light system to get an overview of the results, set individual calculation areas on and off, select spaces for output, and display isolines and false colors on individual surfaces.

Open result tool

The result of tool can be found right above the CAD window. To hide it in each case with a click on and off. You can open the result tool in each mode and check the values at any time.

Result filter

The result Tool automatically displays all calculation surfaces that are available in your particular CAD view. That means you see e.g. all calculation surfaces of a room, if there is a single room visible in the CAD and all calculation areas of a storey if you are in the storey view. Therefore, you can hide them separately in the CAD with the eye - icon.

Isolines and false colors

For each selected area, regardless of whether virtual calculation surface or real surface in the room, you can show or hide isolines or false colors. Select the object and press the desired action. Calculation surfaces are automatically listed in the results tool. With the action "select area" you can select real space surfaces directly in the CAD. These selected surfaces are also available in the outputs.

False colors**Global false colors**

In DIALux evo great value ranges come to fruition. From outdoor lighting with a few lux over the interior illumination between 100 and 1000lx, up to decorative illuminations with 2000lx and more. During the quick and easy interpretation of the calculation results, the false-color view helps. The settings of the false color values are valid for the whole project, so they are also called "global false color". The set value for a color is used in all diagrams and views. Low light levels outdoors, high illuminance levels for indoor and floodlighting.

False colors settings

You can enable and disable the false colors in the display options 200px Display options. You can decide whether DIALux shows illuminances (for virtual calculation surface and real surfaces) or luminance (for real surfaces only) to display with false colors. Switching illuminance [lx] and luminance [cd /m²].

Edit individual values

You can also directly manipulate individual values. By right-clicking on the color scale you set the value and assign a new color to e.g. limits clearly stated.

Documentation

Under documentation you can generate paper or pdf. outputs which serve to document your project.

Selected outputs

Here you can see a list of all the outputs selected at present. A click on the list will open the corresponding output. Below the output you will find the settings for this output if they are available. You can configure up to three different outputs at the same time. Via the "Edit" button all available outputs in the list are displayed.

Printing

Here you start printing or exporting as a pdf. file. First you activate the " Define number of pages" button so that the list of contents and the page changeovers can be generated.You can use any footer text and your own logo in the outputs.

Project information

General information on the project, the customer or the person responsible is entered here. The information on the customer and the responsible person can be saved for use again in a later project.

Configuring templates

Here you can generate your own templates for use in future projects. First you create a new template or make a copy of an existing template. Then you allocate a name and select the outputs which are to be a part of your new template. Any changes are adopted automatically.

TASKS

1. Design a project of a house building with appropriate dimensions and measurements.
2. Adopt a general lighting scheme to achieve targeted lux level(as per standards) using proper utilization profile.
3. Attach the self-generated report.

In the report at least following details should be there,

- 1) Title Page
- 2) Table of Contents
- 3) Project overviews
- 4) Summary
- 5) Luminaries Details
- 6) Calculation Results
 - a) Isolux Contour
 - b) Calculation object points

RESULTS/INTERPRETATIONS

[illegible]

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Department of Electrical Engineering



Course Code and Title: _____

Laboratory Session: No. _____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
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Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

LAB SESSION 11**OPEN ENDED LAB (Commercial building Lighting Scheme Design)****OBJECTIVE**

Implement accent and task lighting on the indoor lighting scheme on Dialux for commercial building.

Theory

Proper lighting can have a significant impact on how you feel in a space, and each space may call for a variety of different lighting requirements. A good lighting setup combines different kinds of lighting to create a welcoming space where you can easily work or relax. There are three basic types of lighting you should layer in a room in order to accomplish this:

- Ambient or general lighting
- Accent lighting
- Task lighting

Ambient or general lighting is a necessary part of any good lighting plan because it provides an overall glow to a room. In addition to setting the tone for the space, ambient lighting creates enough light for you to see and move around comfortably and safely. Ambient lighting is usually created using overhead fixtures like recessed pot lights, track lights, chandeliers and other ceiling lamps, or stand alone fixtures like floor and table lamps.

Accent lighting creates a focal point. It builds upon the ambient lighting of a room by adding dimension, and can be used to draw attention to a feature, like a piece of artwork or a plant, or to highlight a unique design element, like wall texture or decorative coving.

To effectively draw the eye, accent lighting should direct at least three times as much light towards the focal point compared to the rest of the room. This is usually accomplished through track and recessed lighting or wall-mounted fixtures, like picture lights and sconces, which can be angled and directed to create a spotlight. When lighting artwork, it's best to use LEDs. They don't emit UV light and give off almost no heat, ensuring your painting or photography doesn't get damaged over time.

Task lighting is localized and can be provided by a variety of different sources, allowing you the option to adjust the lighting for a work space or chosen area and brighten or darken it in order to suit your needs. Effective task lighting needs to reduce glare and should be bright enough to prevent eye strain, making it ideal for activities like, reading, cooking, crafts and hobbies, studying and work.

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