Reference on electrical installation

40% marks may be obtained by answering ALL questions in Section A.

60% marks may be obtained by answering ALL questions in Section B.

The use of calculators not included in the Approved List is prohibited.

All symbols have their usual meaning unless otherwise defined.

Section A

Answer ALL questions in this section.

A1. a) Fig. A1 shown circuit diagram of a TT system. Suppose you are responsive to the requested by electrical company to modify to a TT and TN-S system, please draw the circuit diagram. (5 marks)

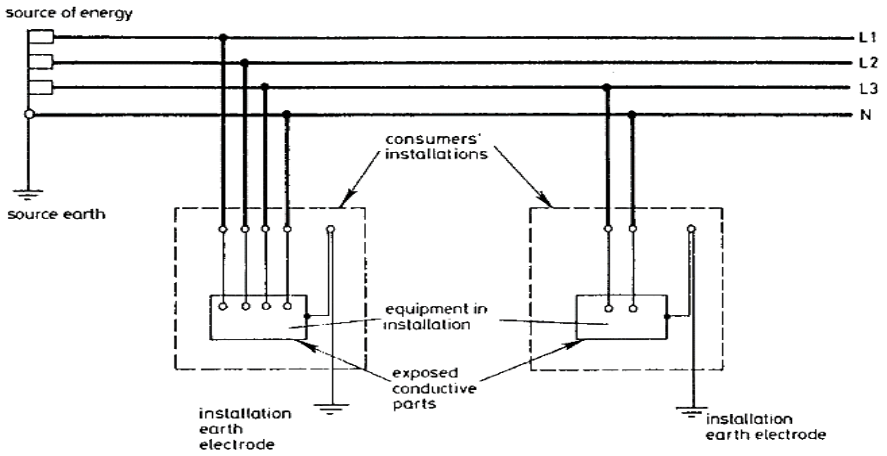


Fig. A1

b) Describe the operation principle of fluorescent lamp. (3 marks)

c) Suggest a green lighting that could replace fluorescent lamp and the reason. (2 marks)

A2. a) Suggest FOUR reinforced protections to reduce the dangerous of people than possible in direct contact with electricity. (4 marks)

b) State three kinds of security system in a building. (3 marks)

c) To qualify as a Registered Electrical Contractor, what is the minimum number of Registered Electrical Worker(s) required in the company? (3 marks)

A3 a) State FOUR cable installation methods. (4 marks)

b) State THREE requirements of overcurrent protective devices. (6 marks)

A4. a) Residual current devices (RCD) is the generic term for a device which monitors the current in the line conductor and the neutral conductor of a circuit in an earthed system, a circuit diagram is shown in Fig. A4. Describe the operation of RCD. (7 marks)

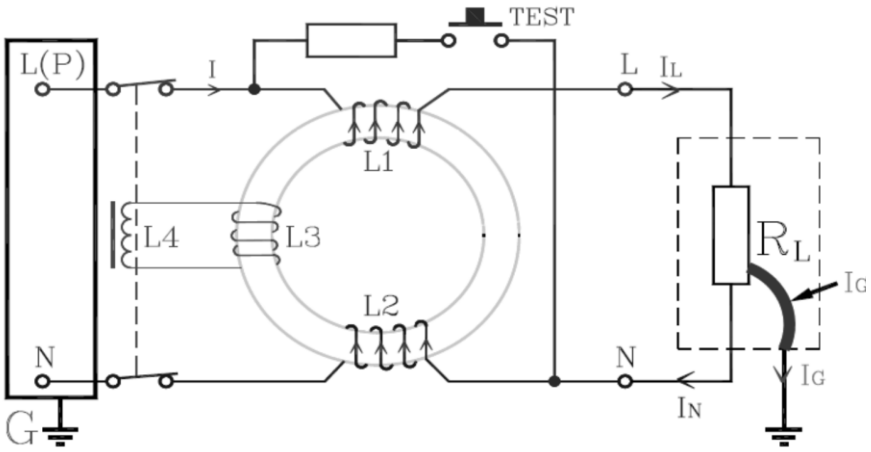


Fig. A4

b) What is the purpose of registration for electrical workers (REW) and electrical contractor (REC)? (3 marks)

Section B

Answer ALL questions in this section.

B1. (a) Determine the Lighting Power Density (LPD) of below situations:

i) Calculate the LPD of luminaries which includes 4 sets of Fluorescent Lamps (FL) where each set of FL consists of two fluorescent tubes, each tube consumes 36W, and the internal floor area is 6 meters by 6 meters. Assume no gear loss. (2 marks)

ii) If the gear loss cannot be omitted in i), and a ballast of 6W is used in each of the fluorescent tube, recalculate the LPD. (2 marks)

(b) In a conduits system, determine how many 1.5mm^2 1-C PVC cables can be enclosed in a 16mm diameter conduit with 9 meter long incorporating 2 bends? [Note: refer to table B1(b) in Appendix.] (4 marks)

(c) A residential flat consisting of three bedrooms, a living room, a kitchen and two bathroom as shown in Fig. B1(c).

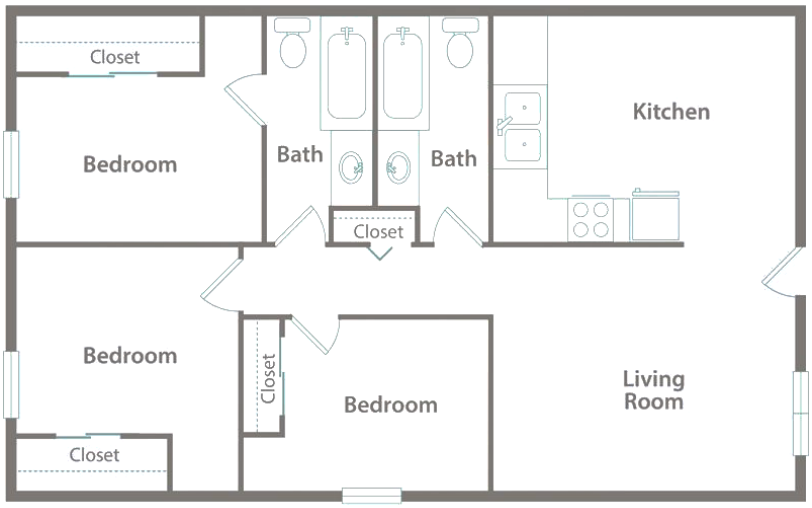


Fig. B1(c)

The unit is supplied from 220V single phase MCB board. Details of loads are:

Each bedroom:

- 1 no. of LED lamp (15W)
- 1 window type air-conditioner with a 7,000 Btu/h

Living room:

- 4 no. LED lamps (15W each)
- 1 window type air-conditioner with 12,000 Btu/h

Kitchen:

- 2 no. of fluorescent light fitting (36W each)

Bathroom:

- 1 no. of fluorescent light fitting (36W)
- 1 no. of small exhaust fan (110W)

Other final circuits are arranged as:

- A 30A ring final circuit using 13A socket outlets serving the living room and the bedrooms;
- A 30A ring final circuit using 13A socket outlets serving the kitchen.

Typical electrical current rating of 1-phase window type air-conditioner is in table B1(c).

Cooling capacity (Btu/h)	**7,000**	**9,000**	**12,000**	**17,000**	**24,300**	**27,000**
Input Current(A)	4.3	5.6	8.6	10.5	15	18.4

Table B1(c)

Determine the current demand for:

i. Lighting circuits; (2 marks)

ii. Air-conditioner circuits; (3 marks)

iii. Socket outlet circuits; (2 marks)

iv. Exhaust fan circuit; (2 marks)

v. The flat (maximum); (2 marks)

vi. What type of MCB should use for air-conditioner if the starting current is approximately 7 type the input current? (1 mark)

B2. (a) Name THREE types of Extra Low Voltage installations in a residential building. (3 marks)

(b) A warehouse measuring 40 m × 28 m has a lighting arrangement consisting of 9 rows of 12 lighting fittings, each housing has 2 nos.

65-Watt fluorescent lamps (The Lighting Design Lumen (LDL) for a 65-Watt fluorescent lamp is 4400 lumens).

i. Find the installed luminous flux(lm) in total; (2 marks)

ii. What is the installed flux per m^2 of floor area. (2 marks)

(c) Fig B2c is a reference circuit to evaluate fault current. A water heater at a kitchen room is directly supplied by the switch at a main switchboard via a $35mm^2$ 2 core armored PVC insulated cable.

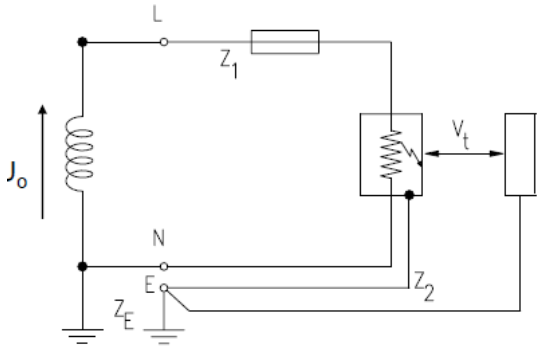


Fig. B2c

Given:

- The impedance of line conductor is $1.302\,\Omega$/km.
- The impedance of $10mm^2$ circuit protective conductor (cpc) is $0.8\,\Omega$/km.
- The Earth fault loop impedance (Z_E) external to the installation is $0.052\,\Omega$.
- The cable length from the main switchboard to water heater is 45m.
- k factor of PVC cable is 115.
- A 125A BS88 fuse is used for overcurrent protection and earth fault protection.

Determine:

(i) The total earth fault loop impedance, Zs; (4 marks)

(ii) The fault current when an earth fault occurs at the water heater; (3 marks)

(iii) The fuse trip time is faster than the required 5s. (3 marks)

(iv) The thermal withstanding capacity of circuit protective conductor (cpc) is suitable to be used. (3 marks)

B3. (a) During purchase of a LED lamp, we describe its light in lumen and describe in lux when light shine upon on a table surface. Distinguish the following light metrics in terms of definition, and unit.

(i) Luminous Flux; (3 marks)

(ii) Illuminance. (3 marks)

(b) Calculate the number of luminaires required for the office.

Given:

1. The size of an office room: 10m (L) × 8m (W) × 2.5m (H).
2. IES recommended illumination level: 500 lux.
3. Working plane: 0.75m.
4. Ceiling/Wall/Floor reflectance: 0.7/0.5/0.1
5. Luminaire: 36W/ T5 2800lm cool white twin lamp.
6. Light Loss Factor, LLF: 0.88
7. Coefficient of Utilization Table:

Room Index RI	Room Reflectance								
	C	W	F	C	W	F	C	W	F
	0.7	0.5	0.1	0.7	0.3	0.1	0.7	0.5	0.3
2.0	0.60			0.57			0.66		
2.5	0.62			0.60			0.69		
3.0	0.64			0.62			0.72		
4.0	0.66			0.64			0.75		

Table B3(b)

(i) The reflectance of ceiling, wall and floor are 70%, 50% and 20% respectively, evaluate the coefficient of utilization factor. (2 marks)

(ii) Calculate the number of luminaires required. (2 marks)

(iii) The lighting arrangement (rows by columns). (2 marks)

(iv) Axial spacing. (2 marks)

(v) Transverse spacing. (2 marks)

(vi) Draw the lighting layout. (4 marks)

- End of Questions -

Useful Formula

Caution! The following formula is intended to be an aid to memory and do not represent all the formulas needed for answering the questions. Also not all the formulas may be needed.

Electric Supply:

Single Phase $I = \frac{P}{V}$

Three Phase $I = \frac{P}{\sqrt{3} \times V_L}$

Where I : Electrical Current
P : Electrical Power
V : Phase Voltage
V_L : Line Voltage

Adiabatic Equation

$$I^2 t \leq k^2 S^2$$

Where
k is constant related to materials
S is cross section area of conductor (mm^2)
t is disconnection time
I is minimum prospective fault current

$P = V \cdot I \cos\theta$ (where $\cos\theta$ is power factor or pf)

Lighting and illumination:

$$Number\ of\ Lamp = \frac{\text{illuminance} \times \text{area}}{\text{Lumens per lamp} \times \text{CU} \times \text{LLF}}$$

Room Index (RI):

$$RI = \frac{L \times W}{H_{RC} \times (L + W)}$$

Illuminance:

$$E = \frac{\emptyset_{total} \times CU \times LLF}{\text{Area}}$$

Where LLF is light loss factor and CU is coefficient of utilization.

Lighting Power Density (LPD) is defined as the electrical power consumed by fixed lighting installations per unit floor area of an illuminated space. The unit of LPD is watt per square meter.

$$LPD = \frac{\text{Total wattage of the fixed lighting installations}}{\text{Internal floor area of that space}} \quad W/m^2$$

Appendix

Cable Factors and Conduit Factors for Conduit Exceeding 3 m in length or in Runs Incorporating Bends or Sets

(a) Cable Factor

Type of Conductor	Conductor Cross-Sectional Area (mm^2)	Factor
Solid or stranded	1	16
	1.5	22
	2.5	30
	4	43
	6	58
	10	105

Table B1(b)-1

(*b*) Conduit Factor

Length of Run (*m*)	Conduit Diameter (mm)																			
	16	20	25	32	16	20	25	32	16	20	25	32	16	20	25	32	16	20	25	32
	Straight				One bend				Two bends				Three bends				Four bends			
1	Covered by Tables 14(2) (*a*) and (*b*)				188	303	543	947	177	286	514	900	158	256	463	818	130	213	388	692
1.5					182	294	528	923	167	270	487	857	143	233	422	750	111	182	333	600
2					177	286	514	900	158	256	463	818	130	213	388	692	97	159	292	529
2.5					171	278	500	878	150	244	442	783	120	196	358	643	86	141	260	474
3					167	270	487	857	143	233	422	750	111	182	333	600				
3.5	179	290	521	911	162	263	475	837	136	222	404	720	103	169	311	563				
4	177	286	514	900	158	256	463	818	130	213	388	692	97	159	292	529				
4.5	174	282	507	889	154	250	452	800	125	204	373	667	91	149	275	500				
5	171	278	500	878	150	244	442	783	120	196	358	643	86	141	260	474				
6	167	270	487	857	143	233	422	750	111	182	333	600								
7	162	263	475	837	136	222	404	720	103	169	311	563								
8	158	256	463	818	130	213	388	692	97	159	292	529								
9	154	250	452	800	125	204	373	667	91	149	275	500								
10	150	244	442	783	120	196	358	643	86	141	260	474								

Table B1(b)-2

Allowance for Diversity

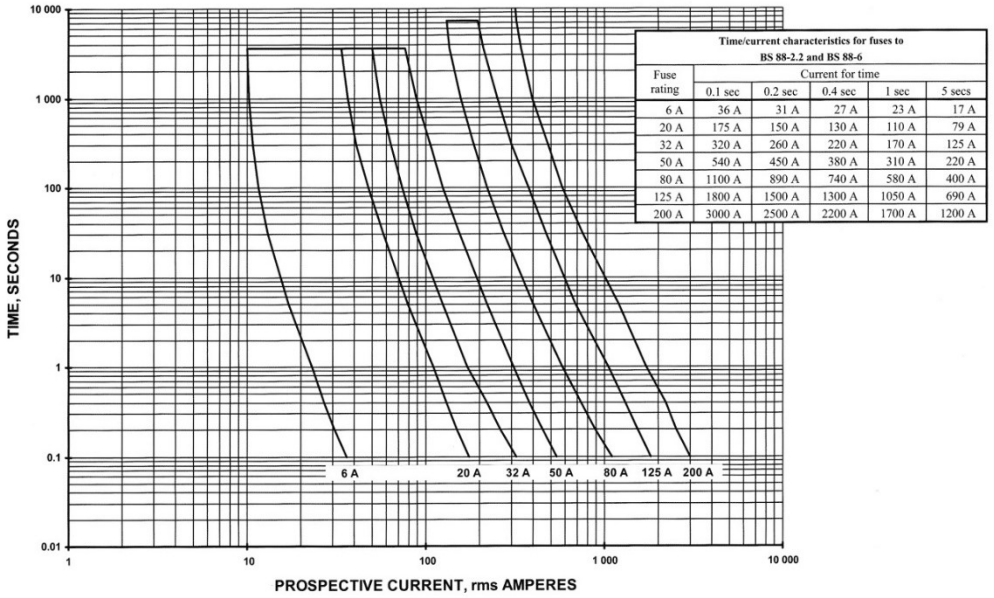
This table is applicable to installations having a current demand not exceeding 400 A in each phase.

Purpose of Conductors or Switchgear to which Diversity Applies	Type of Premises		
	Individual Household Installations, Individual Dwellings of a Block	Small shops, Stores, Offices and Business Premises	Small Hotels, Boarding Houses, Guest Houses, etc.
1. Lighting	66% of total current demand	90% of total current demand	75% of total current demand
2. Heating and Power (Also see 3 to 10 below)	100% of total current demand up to 10 amperes+50% of any current demand in excess of 10 amperes	100% f.l. of largest appliance+75% f.l. of remaining appliances	100% f.l. of largest appliance+80% f.l. of 2nd largest appliance+60% f.l. of remaining appliances
3. Cooking Appliances	10 amperes+30% f.l. of connected cooking appliances in excess of 10 amperes+5 amperes if socket outlet incorporated in unit	100% f.l. of largest appliance+80% f.l. of 2nd largest appliance+60% f.l. of remaining appliances	100% f.l. of largest appliance+80% f.l. of 2nd largest appliance+60% f.l. of remaining appliances
4. Motors (other than lift motors, see 8)	—	100% f.l. of largest motor+80% f.l. of 2nd largest motor+ 60% f.l. of remaining motors	100% f.l. of largest motor+50% f.l. of remaining motors
5. Water-Heaters (instantaneous type)	100% f.l. of largest appliance+100% f.l. of 2nd largest appliance+25% f.l. of remaining appliances	100% f.l. of largest appliance+100% f.l. of 2nd largest appliance+25% f.l. of remaining appliances	100% f.l. of largest appliance+100% f.l. of 2nd largest appliance+25% f.l. of remaining appliances
6. Water Heaters (thermostatically controlled)	No diversity allowable Note: It is important to ensure that the distribution board is of sufficient rating to take the total load connected to it without the application of any diversity.		
7. Thermal Storage Space Heating Installations			
8. Lift motors	Note: Subject to requirements specified by the lift engineer registered under Cap. 327, Lifts & Escalators (Safety) Ordinance.		
9. Water Pumps	100% f.l. of the largest pump motor and 25% of the remaining motors		

Table B2(b)-1

Purpose of Conductors or Switchgear to which Diversity Applies	Type of Premises		
	Individual Household Installations, Individual Dwellings of a Block	Small shops, Stores, Offices and Business Premises	Small Hotels, Boarding Houses, Guest Houses, etc.
10. Air conditioners	100% f.l. of the air-conditioner(s) in the bed-room(s) or in the living room(s), whichever is larger and 40% f.l. of the remaining air-conditioner(s)	100% of current demand of largest point of utilisation+ 75% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation+ 75% of current demand of every other point of utilisation
11. Arrangements of Final Circuits in accordance with code 6D	100% of current demand of largest circuit+30% of current demand of every other circuit	100% of current demand of largest circuit+ 40% of current demand of every other circuit	
12. Arrangements of Final Circuits in accordance with code 6E	100% of current demand of largest circuit+40% of current demand of every other circuit	100% of current demand of largest circuit+ 50% of current demand of every other circuit	
13. Fixed Equipment of the same type e.g. Refrigerators and freezers other than those listed above	100% of current demand of largest point of utilisation+ 40% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation+ 75% of current demand of every other point of utilisation	100% of current demand of largest point of utilisation+ 75% of current demand of every point in main rooms (dining rooms, etc.) + 40% of every other point of utilisation

Table B2(b)-2

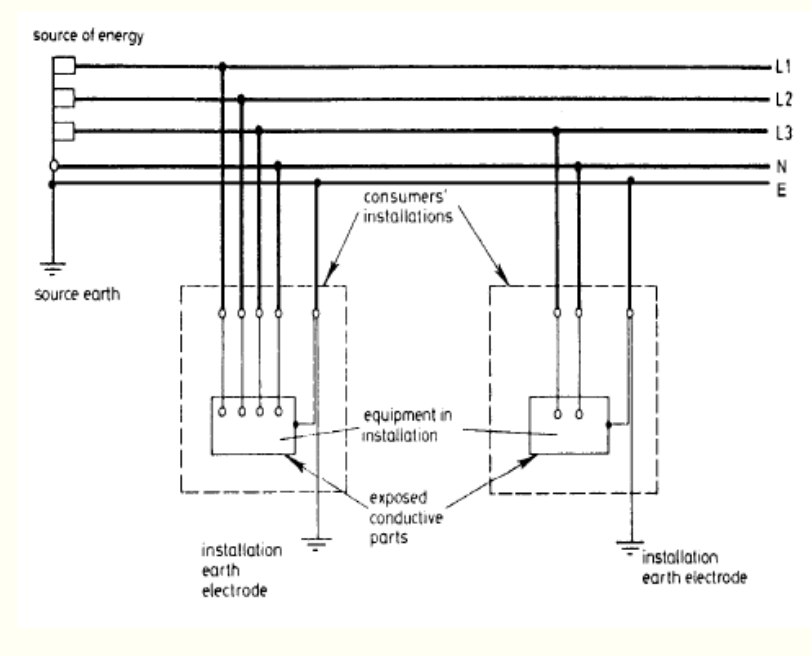


Time/current characteristics for fuses to BS 88-2.2 and BS 88-6

Fuse rating	Current for time				
	0.1 sec	0.2 sec	0.4 sec	1 sec	5 secs
6 A	36 A	31 A	27 A	23 A	17 A
20 A	175 A	150 A	130 A	110 A	79 A
32 A	320 A	260 A	220 A	170 A	125 A
50 A	540 A	450 A	380 A	310 A	220 A
80 A	1100 A	890 A	740 A	580 A	400 A
125 A	1800 A	1500 A	1300 A	1050 A	690 A
200 A	3000 A	2500 A	2200 A	1700 A	1200 A

Graph B2(c)

- End of Paper –

Question No.:	A1 (related topic area: LV, lighting)	
(a)	Separate neutral and protective conductors throughout the system. All exposed conductive parts of an installation are connected to the protective conductor provided by the source via the earthing terminal of the installation 	
(b)	The fluorescent lamp is an electric discharge source in which light is produced by the fluorescence of phosphors activated by ultraviolet energy from a low pressure mercury.	
(c)	Since mercury is toxic, LED is a better replacement of fluorescent lamp in green lighting.	

Question No.:	A2 (related topic area: LV, ELV)	
(a)	Reinforced basic protection from electricity: - By insulation of live parts - By barriers or enclosures - By obstacles - By placing out of reach (1 % each)	
(b)	1. CCTV surveillance system 2. Access control system 3. Watchman tour system	
(c)	ONE Registered Electrical Worker is required.	
Question No.:	A3 (related topic area: LV, ELV)	
(a)	1. Surface wiring 2. Conduit system 3. Cable tray 4. Cable ladder 5. Trunking system (Any 4, 1% each)	
(b)	Requirements of overcurrent protective devices are: -be operated automatically -have adequate breaking capacity and making capacity -be suitably located -be constructed so as to prevent danger from overheating, arcing or the scattering of hot particles when they come to operation -to permit ready restoration of the supply without danger . (Any 3, 2% in each descriptive part)	

Question No.: A4 (related topic area: ___LV_____)		
(a)	- a normal healthy circuit, the vector sum of the live and neutral current values added together will be zero. - Current flowing to earth, due to a line earth fault will return via the earth conductor, and regardless of load conditions, will be registered as a fault. - This current flow will give rise to a residual current (Ires) which will be detected by the device. - If the Ires exceeds the rated sensitivity of the RCD, it will automatically activate a tripping of the faulty circuit, thereby protecting people, equipment and buildings from the risk of electrocution and fire.	
(b)	To ensure that such work is carried out only by qualified electrical workers.	

Question No.: B1 (related topic area: LV, Lighting)		
(a)	Lighting Power Density (LPD) is defined as $\text{LPD} = \frac{\text{Total wattage of the fixed lighting installations}}{\text{Internal floor area of that space}}$ W/m^2 i) LPD of luminarie = (4×2× 36) /(6×6)=8.0 W/m^2 ii) LPD of luminaire =(4×2×(36+5)) /(6×6)=9.1 W/m^2	
(b)	Cable factor is 22 and conduit factor is 91 from the table. 91/22 = 4.1 and choose the smaller integer is 4, Thus, the number of cable that can be accommodated is 4.	
(c)	(i) Lighting current demand =(5×15+4×36×1.8)/220 = 1.52A (ii) Air condition current demand = 8.6×100% + 4.3 ×3×40% =13.76A (iii) Socket outlet current demand =30+(30×40%) = 42A (iv) Small fan current demand = 2×110/220 = 1A (v) Total current demand = 1.52 + 13.76 + 42 + 1 = 58.28A **(vi) Type C MCB will be chosen.**	

Question No.: B2 (related topic area: Lighting, ELV)		
(a)	Any THREE types of Extra Low Voltage installations as below: 1. Communal Aerial Broadcast Distribution (CABD) system 2. Card Access Control system 3. Closed-Circuit Television (CCTV) Surveillance system 4. Home Automation system 5. Public Address system 6. Radio Paging and Walkie Talkie system 7. Security Burglar Alarm system 8. Watchman Tour system 9. Building Automation System (BAS) 10. Building Management System (BMS) (Any THREE above)	
(b)	i. Install luminous flux (lm) = 9) Install luminous flux (lm) = 9×12×2×4400 = 950,400 lm ii. 950400/ (40×28) = 848.57 Lux	
(c)	(i) Z_1=45×1.302/1000=0.0586Ω Z_2 = 45 × 0.8 /1000 = 0.036Ω Z_E =0.052Ω (given) Zs = Z_1 + Z_2 + Z_E = 0.0586 + 0.036 + 0.052 = 0.1466Ω (ii) fault current = 220 / 0.1466 = 1500A (iii) from table could find 0.3 s trip time (iv) $k^2S^2 \geqq I^2t$ $115^2S^2 \geqq 1500^2$ (0.3) $S \geqq 7.144mm^2$ $10mm^2$ cable is suitable	
Question No.: B3 (related topic area: Lighting, ELV)		
(a)	(i)Luminous Flux: Luminous flux is the total amount of light produced by a light source. The unit is Lumen. (ii)Illuminance: Illuminance is the amount of light striking or "incident upon" a surface. The unit is Lux.	
(b)	i. Calculate the RI: $RI = \frac{L \times W}{H_{RC} \times (L + W)} = \frac{10 \times 8}{(2.5 - 0.75) \times (10 + 8)} = 2.53 \simeq 2.5$ ii. To find the CU: From table, use the column 0.7/0.5/0.1, the CU is 0.62	

iii. Use formula to find the number of luminaires, *N*.

$$E_{wp} = \frac{\Phi_{total}}{Area_{wp}} \times CU \times LLF$$

$$E_{wp} = 500\ lux$$

$$\Phi_{total} = 2 \times 2800 \times N\ = 5600\ N$$

CU = 0.62

LLF = 0.88

$$500 = \frac{5600\ N}{12 \times 7.5} \times 0.62 \times 0.88$$

$$N = 13$$

Take N = 15

The lighting layout is 3 by 5.

iv. 10/5=2.5m

v. 8/3=2.66m

vi.