UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: February 2020

Module Number: EE8202 **Module Name: Electrical Systems in Buildings**

[Three Hours]

[Answer **all questions**, each question carries 10 marks]

Q1. a) Explain what the lighting power density for a room is. State the measures you could take to reduce the lighting power density at the design stage of lighting.

[1.0 Mark]

b) Lighting layout for an office room of size 5 m x 5 m is to be designed using Average Illuminance Method. Illuminance required is 500 lux over the working plane. Assume utilization factor = 0.6, maintenance factor = 0.8, lamps are going to be installed in luminaires having light output ratio of 0.9, each of which can have one lamp inside.

i) Calculate the number of lamps required if 25 W, 3070 lm/lamp rated lamps are used.

ii) Calculate the number of lamps required if 35 W, 3250 lm/lamp rated lamps are used.

iii) Out of the two lamps considered in part i) and part ii), state with reasons which lamp is most suitable in this stage of design.

[5.0 Marks]

c) Briefly explain why it is important to consider the diversity factor and utilization factor for electrical installation demand calculations.

[1.0 Mark]

d) Part of a distribution system of a certain installation is shown in Figure Q1. Distribution board (DB01) has to feed following loads.

- 50 Nos. of 230 V, 40 W incandescent lamps
- 4 Nos. of 400 V, 8.5 kW, 0.85 PF, 3-phase air conditioners
- 3 Nos. of 1500 W, 230 V, unity PF single-phase instantaneous water heaters
- 3 Nos. of 2.5 kW, 400 V, unity PF, 3-phase cookers

i) Determine the total demand of DB01. Allowances for diversities are given in the Table Q1.

ii) If the earthing system of this installation is TT, draw a suitable single line diagram for the DB01. (Sizing of cables and protective devices are not needed).

[3.0 Marks]

Q2. a) Compare and contrast two earthing arrangements TT and IT with suitable diagrams.

[2.5 Marks]

b) A 400 V three-phase load is wired using single core Cu/PVC/PVC cables in a conduit on a wall. Size of each phase conductor cable is 10 mm² and it was found that the source impedance is 0.01 Ω/phase. By considering the worst case, calculate the earth fault current at the load end and determine the minimum cross section area of the required protective earth (PE) conductor for this circuit using adiabatic equation $A = \frac{\sqrt{I^2 t}}{k}$, where k = 115 and fault clearing time = 0.4 s. Note that all the notations have their usual meanings. Assume that earthing arrangement is TN-S and the distance between source and load is 50 m. For answering this question refer Annex 2 for necessary data.

[4.5 Marks]

c) Following data are available for designing a grounding system of a substation.

Fault duration t_f	= 0.5 s
Soil resistivity ρ	= 300 Ωm
Crushed rock resistivity ρ_S	= 3000 Ωm
Thickness of crushed rock surfacing h_S	= 100 mm
Depth of grid burial h	= 500 mm
Available grounding area A	= 85 m x 70 m
Fault current I_G	= 6814 A
Initial mesh grid size (spacing between parallel conductors (D) in each square; in x and y directions)	= 5 m x 5 m
Correction factor for grid geometry K_i	= 1.565
Spacing factor for mesh voltage K_m	= 0.736
Spacing factor for step voltage K_S	= 0.440
The reduction factor C_S	= 0.72

Grounding resistance is given by: $R_g = \rho\left[\frac{1}{L_C} + \frac{1}{\sqrt{20A}}\left(1 + \frac{1}{1+h\sqrt{\frac{20}{A}}}\right)\right]$

Mesh voltage is given by: $E_m = \frac{\rho K_m K_i I_G}{L_C}$

Step voltage is given by: $E_s = \frac{\rho K_s K_i I_G}{0.75 L_C}$

Tolerable touch voltage is given by: $E_{touch} = (1000 + 1.5 C_S \rho_S)\frac{k}{\sqrt{t_f}}$

Tolerable step voltage is given by: $E_{step} = (1000 + 6 C_S \rho_S)\frac{k}{\sqrt{t_f}}$

L_C is the total length of the conductor in horizontal grid and other notations have their usual meanings. Check whether the initial design satisfies with the safety criteria. Consider average body weight as 70 kg and corresponding k = 0.157.

[3.0 Marks]

Q3. a) Briefly explain three methods of protection against indirect contacts in an electrical system.

[1.5 Marks]

b) i) A three-phase 50 kW, 400 V, 0.8 PF load is to be connected using single core Cu/PVC/PVC cables. There are 6 cables running in the same path and the temperature of the environment is 35 ^{0}C. Cables are to be installed in a cable tray. The distance from supply point to load is 175 m. Select a suitable cable size for this application. Cables are installed at touching condition. For answering this question refer Annex 1 and Annex 2 for necessary data.

ii) If the starting current of the load mentioned in part i) is 280 A and minimum fault current is 510 A, then select a suitable Miniature Circuit Breaker (MCB) for this load where circuit breaker rated current can be selected from 6A, 10A, 16A, 20A, 25A, 32A, 40A, 60A, 80A, 100A, 125A, 160A, 200A, 250A, 300A, 400A, 500A, 600A, 800A, 1000A, 1200A and 1500A.

[5.5 Marks]

c) i) With the aid of suitable diagram(s), briefly explain why the corner points of a building are more vulnerable to lightning strikes.

ii) Explain what is equipotential bonding at the boundary of Lightning Protection Zone (LPZ) based on IEC 62305-4 standard.

iii) Figure Q3 in Annex 3 shows the plan view of earth wires and masts arrangement in a switchyard. Show the protection area which is covered by the combination of shielding wires and masts by shading that on Figure Q3. Neglect sagging of earth wire. Diagrams need not to be in scale. Attach Annex 3 with your answer to the answer script.

[3.0 Marks]

Q4. a) Discuss the advantages of the IP based extra low voltage systems of modern buildings.

[1.5 Marks]

b) Discuss the advantages of having a Building Management System (BMS) in a building.

[1.5 Marks]

c) A 1/4 inch camera with a height constant of 2.7 and a width constant of 3.6 is viewing an entrance gate of a building. The lorry coming through the gate is the critical view. Distance between the camera and the gate is 100 m. Width of the gate is 12 m and the front dimensions of the lorry are 4 m x 4 m.

i) Determine the focal length, the scene height, the scene area and the critical area of view.

ii) Is the lorry within the identification area? Justify your answer.

[3.0 Marks]

d) Figure Q4 in Annex 4 shows a layout drawing of a workshop. It is required to propose a suitable Closed-Circuit Television (CCTV) camera system for the workshop covering all the critical areas.

i) Propose suitable CCTV cameras for selected locations stating camera type, focal length, covering area and view angle. Use Annex 4 to draw your design and attach it with your answer script. State any assumption you made.

ii) Draw a schematic CCTV diagram with Network Video Recorder (NVR) and IP cameras.

[4.0 Marks]

Q5. a) Discuss the advantages of a Private Automatic Branch Exchange (PABX) system.

[1.5 Marks]

b) Briefly explain the function and advantages of a car park management system.

[2.0 Marks]

c) Draw a schematic diagram of IP based Fire detection system and list the components.

[1.5 Marks]

d) Briefly explain the function of fire detection and protection systems in a multi storied building.

[2.0 Marks]

e) Figure Q5 in Annex 5 shows a layout drawing of a workshop. Take the covering radiuses of smoke detector and heat detector as 7.5 m and 5.3 m, respectively. Draw a suitable fire detection system for the workshop. Use Annex 5 to draw your design and attach it with your answer script. State any assumption you made.

[3.0 Marks]

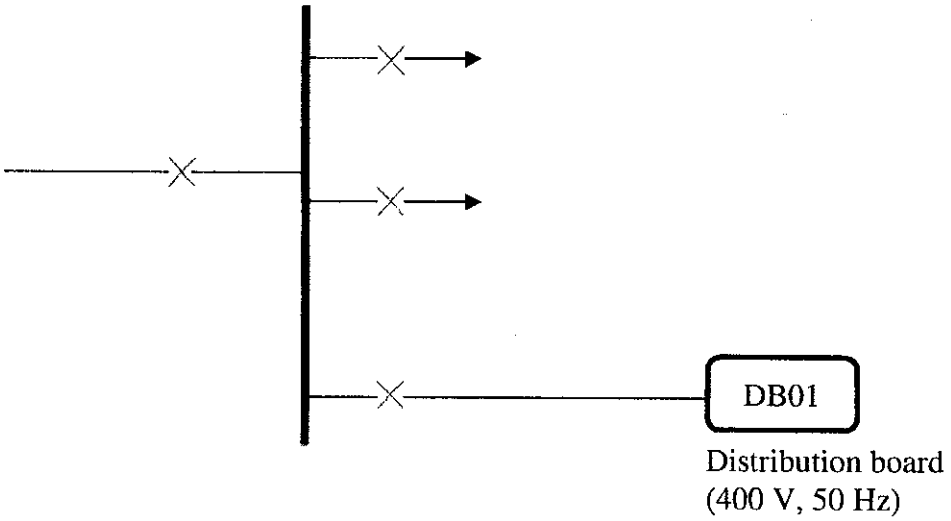


Figure Q1

Table Q1- Allowance for diversity

Type of final circuit	**Diversity**
Lighting	90%
Heating	100%X + 75%(Y+Z)
Cookers	100%X + 80%Y + 60%Z
Motors	100%X + 80%Y + 60%Z
Instantaneous type water heaters	100%X + 100%Y + 25%Z
Thermostatic water heaters	100%
Air conditioners	70%
Sockets and stationery equipment	100%X + 75%(Y+Z)

X is the full load current of the largest appliance or circuit
Y is the full load current of the second largest appliance or circuit
Z is the full load current of the remaining appliances or circuits

TABLE 4D1A - Single-core 70°C thermoplastic insulated cables, non-armoured, with or without sheath (COPPER CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes)

Ambient Temperature: 30°C
Conductor Operating Temperature 70°C

Conductor Cross - Sectional Area	Reference Method A (enclosed in conduit in thermally insulating wall etc)		Reference Method B (enclosed in conduit on a wall or in trunking etc)		Reference Method C (Clipped Direct)		Reference Method F (In free air or on a perforated cable tray horizonal or vertical)				
							Touching			Spaced By One Dlameter	
	2 Cables, Single - phrase a.c. or d.c	3 or 4 cables, three - phase a.c	2 Cables, single - phrase a.c. or d.c.	3 or 4 cables, three - phrase a.c.	2 cables, single - phrase a.c. or d.c. flat and touching	3 or 4 cables, three - phrase a.c. flat and touching or trefoil	2 Cables, single - phrase a.c. or d.c. flat	3 cables, three - phrase a.c. flat	3 cables, three - phrase a.c trefoil	2 Cables, single phrase a.c. or d.c. or 3 cables three-phrase a.c. flat	
										Horizontal	Vertical
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	11	10.5	13.5	12	15.5	14	-	-	-	-	-
1.5	14.5	13.5	17.5	15.5	20	18	-	-	-	-	-
2.5	20	18	24	21	27	25	-	-	-	-	-
4	26	24	32	28	37	33	-	-	-	-	-
6	34	32	41	36	47	43	-	-	-	-	-
10	46	42	5	50	65	59	-	-	-	-	-
16	61	56	76	68	87	79	-	-	-	-	-
25	80	73	101	98	114	104	131	114	110	146	130
35	99	89	125	110	141	129	162	143	137	181	162
50	119	108	151	134	182	167	196	174	167	219	197
70	151	136	182	171	234	214	251	225	216	281	254
95	182	164	232	207	284	261	304	275	264	341	311
120	210	188	269	239	330	303	352	321	308	396	362
150	240	216	300	262	381	439	406	32	356	456	419
185	273	245	341	296	436	400	463	427	409	521	480
240	321	286	400	346	515	472	546	507	485	615	569
300	367	328	458	394	594	545	629	587	561	709	659
400	-	-	546	467	694	634	754	689	656	852	795
500	-	-	626	533	792	723	868	789	749	982	920
630	-	-	720	611	904	826	1005	905	855	1138	1070
800	-	-	-	-	1030	943	1086	1020	971	1265	1188
1000	-	-	-	-	1154	1058	1216	1149	1079	1420	1337

Annex 1

VOLTAGE DROP (per ampere per metre):

Conductor Operating Temperature: 70°C

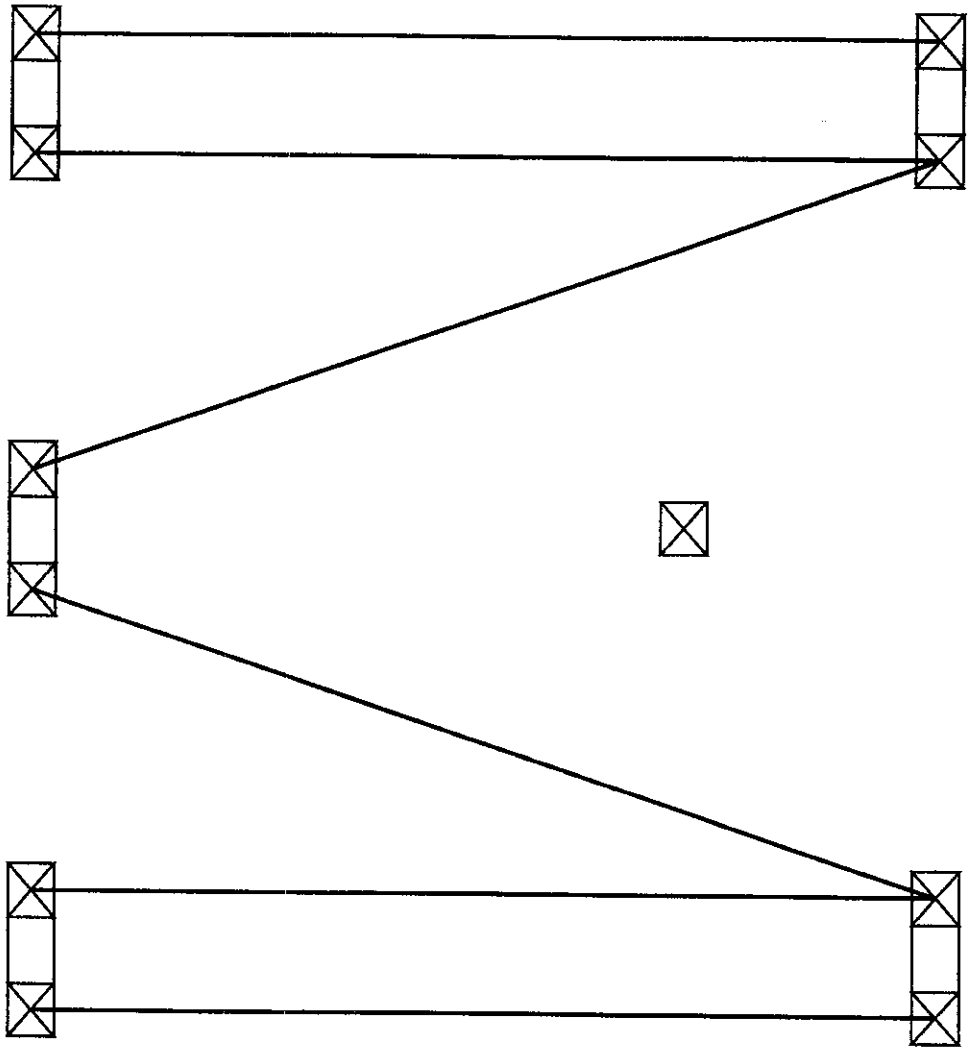
Conductor Cross Sectional area	2 Cables d.c.	2 Cables, single - phrase a.c.									3 or 4 cables, three - phrase a.c.									
		Reference Methods A & B (Enclosed in conduit or trunking)			Reference Methods C & F (Clipped direct, on tray or in free air)						Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C & F (Clipped direct, on tray or in free air)								
					Cables Touching			Cables Spaced*						Cables Touching trefoil			Cables Touching Flat			Cables Spaces*, Flat		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
1	44	44			44			44			38			38			38			38		
1.5	29	29			29			29			25			25			25			25		
2.5	18	18			18			18			15			15			15			15		
4	11	11			11			11			9.5			9.5			9.5			935		
6	7.3	7.3			7.3			7.3			6.4			6.4			6.4			6.4		
10	4.4	4.4			4.4			4.4			3.8			3.8			3.8			3.8		
16	2.8	2.8			2.8			2.8			2.4			2.4			2.4			2.4		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
25	1.75	1.80	0.33	1.80	1.75	0.20	1.75	1.75	0.29	1.80	1.50	0.29	1.55	1.50	0.175	1.50	1.50	0.25	1.55	1.50	0.32	1.55
35	1.25	1.30	0.31	1.30	1.25	0.195	1.25	1.25	0.28	1.30	1.10	0.27	1.10	1.10	0.170	1.10	1.10	0.24	1.10	1.10	0.32	1.15
50	0.93	0.95	0.30	1.00	0.93	0.190	0.95	0.93	0.28	0.97	0.81	0.26	0.85	0.80	0.165	0.82	0.80	0.24	0.84	0.80	0.32	0.86
70	0.63	0.65	0.29	0.72	0.63	0.185	0.66	0.63	0.27	0.69	0.56	0.25	0.61	0.55	0.160	0.57	0.55	0.24	0.60	0.55	0.31	0.63
95	0.46	0.49	0.28	0.56	0.47	0.180	0.50	0.47	0.27	0.54	0.42	0.24	0.48	0.41	0.155	0.43	0.41	0.23	0.47	0.40	0.31	0.51
120	0.36	0.39	0.27	0.47	0.37	0.175	0.41	0.37	0.26	0.45	0.33	0.23	0.41	0.32	0.150	0.36	0.32	0.23	0.40	0.32	0.30	0.44
150	0.29	0.31	0.27	0.41	0.30	0.175	0.34	0.29	0.26	0.39	0.27	0.23	0.36	0.26	0.150	0.30	0.26	0.23	0.34	0.26	0.30	0.40
185	0.23	0.25	0.27	0.37	0.24	0.170	0.29	0.24	0.26	0.35	0.22	0.23	0.32	0.21	0.145	0.26	0.21	0.22	0.31	0.21	0.30	0.36
240	0.180	0.195	0.26	0.33	0.185	0.165	0.25	0.185	0.25	0.31	0.17	0.23	0.29	0.160	0.145	0.22	0.160	0.22	0.27	0.160	0.29	0.34
300	0.145	0.160	0.26	0.31	0.150	0.165	0.22	0.150	0.25	0.29	0.14	0.23	0.27	0.130	0.140	0.190	0.130	0.22	0.25	0.130	0.29	0.32
400	0.105	0.160	0.26	0.29	0.120	0.160	0.20	0.115	0.25	0.27	0.12	0.22	0.25	0.105	0.140	0.175	0.105	0.21	0.24	0.100	0.29	0.31
500	0.086	0.110	0.26	0.28	0.098	0.155	0.185	0.093	0.24	0.26	0.10	0.22	0.25	0.086	0.135	0.160	0.086	0.21	0.23	0.081	0.29	0.30
630	0.068	0.094	0.25	0.27	0.081	0.155	0.175	0.076	0.24	0.25	0.08	0.22	0.24	0.072	0.135	0.150	0.072	0.21	0.22	0.066	0.28	0.29
800	0.053	-			0.068	0.150	0.165	0.061	0.24	0.25	-			0.060	0.130	0.145	0.060	0.21	0.22	0.053	0.28	0.29
1000	0.042	-			0.059	0.150	0.160	0.050	0.24	0.24	-			0.052	0.130	0.140	0.052	0.20	0.21	0.044	0.28	0.28

NOTE:

* Spacings larger than one cable diameter will result in a larger voltage drop.

Annex 2

Annex 3



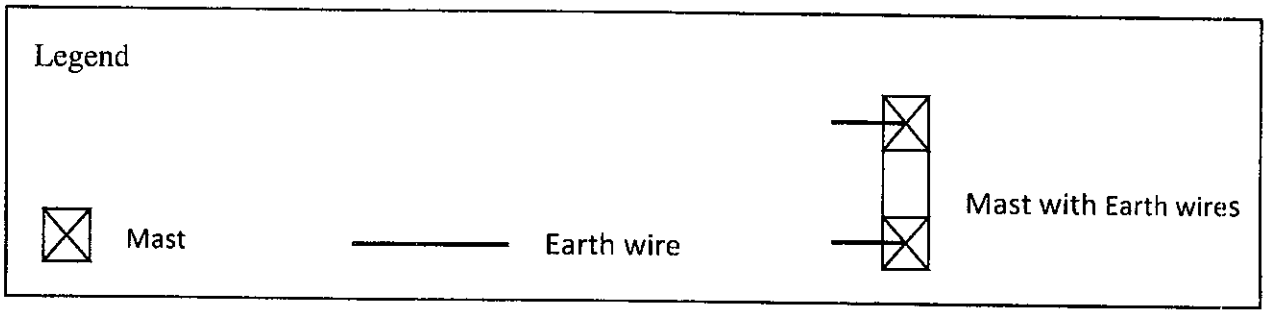


Figure Q3

Annex 4

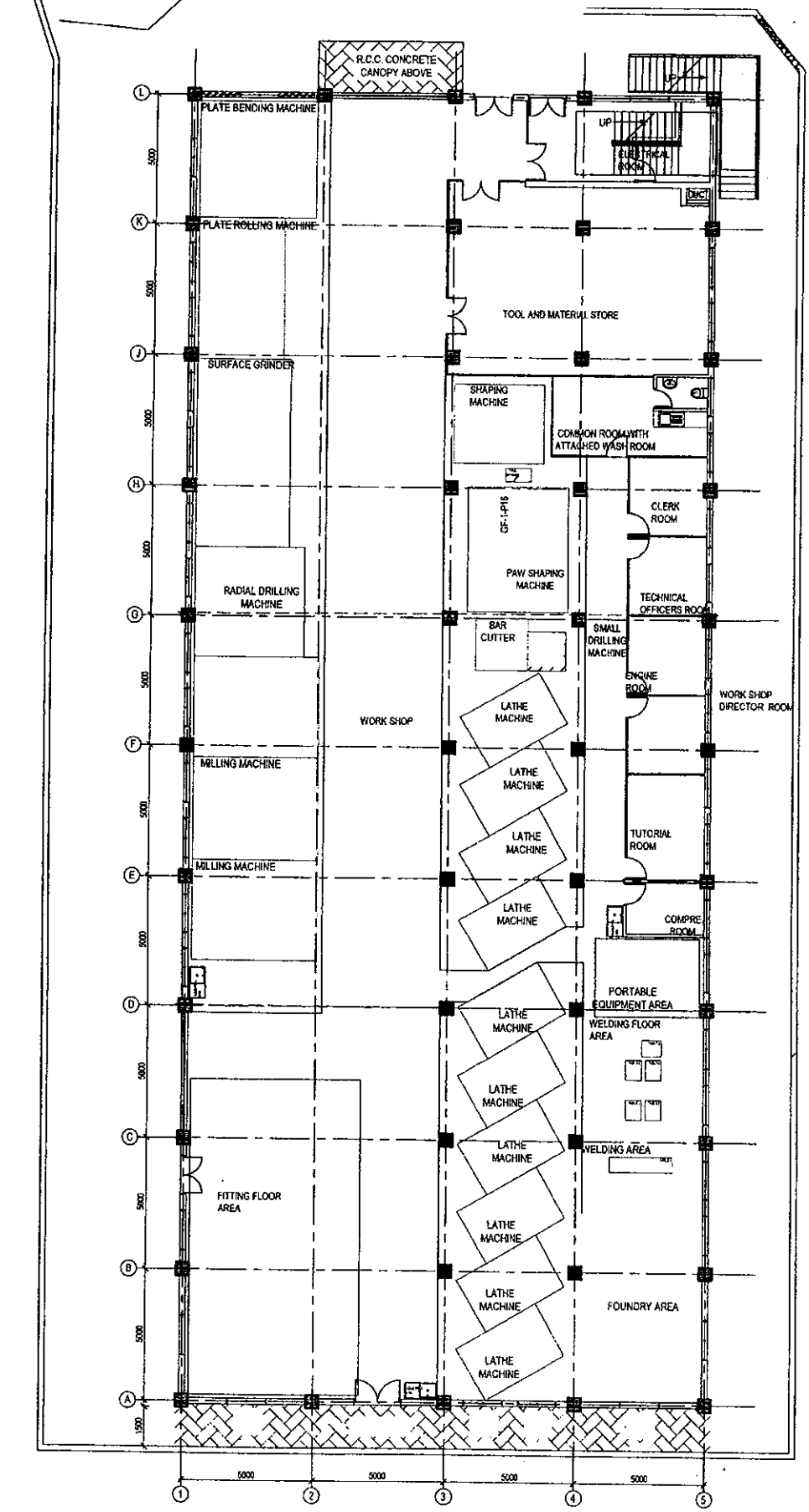


Figure Q4

Annex 5

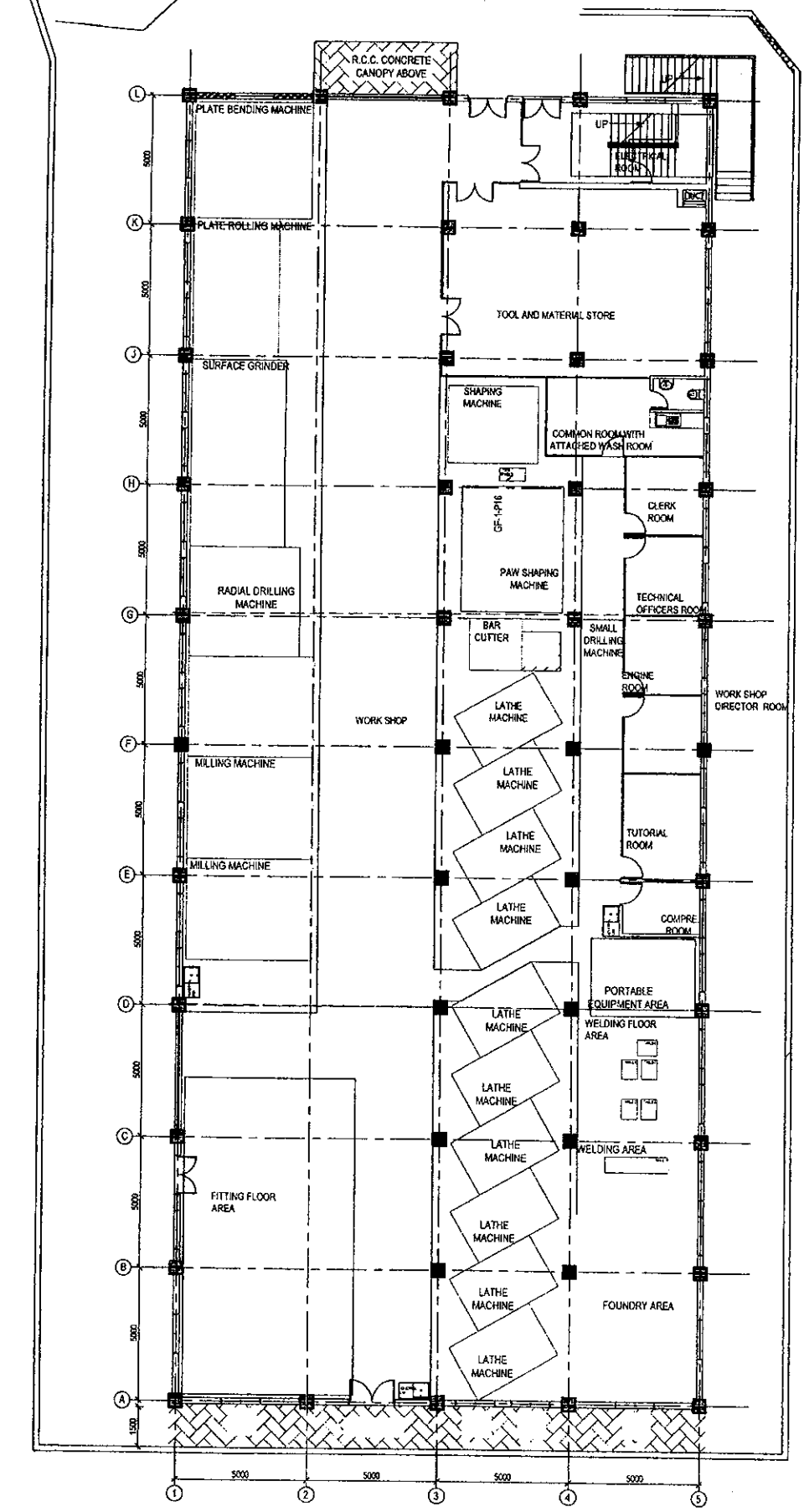


Figure Q5