

**Electrical & Mechanical
Services Department**

機電工程署

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香港工程師學會

**Hong Kong
Examinations and
Assessment Authority**
香港考試及評核局

**EXAMINATION
FOR REGISTRATION AS A
GRADE C ELECTRICAL WORKER**

**EXAMINATION SYLLABUS
AND SAMPLE QUESTIONS**

**C 級電業工程人員註冊考試
考試大綱及樣本試題**

CONTENTS 目錄**Page No. 頁數**

Examination Syllabus for Registration as a Grade C Electrical Worker	2
Sample Examination Questions for Part A	4
Sample Examination Questions for Part B	12
C 級電業工程人員註冊考試大綱	20
甲部試題樣本	22
乙部試題樣本	30

Examination Syllabus for Registration as a Grade C Electrical Worker

Reference: Code of Practice for the Electricity (Wiring) Regulations, IEE Wiring Regulations, local Supply Rules, Electrical Engineering handbooks, relevant international standards and publications in connection with design, installation, commissioning and maintenance of electrical installations.

1. General Knowledge

- (a) Familiarization of relevant local legislative regulations and Electricity Ordinance, such as requirements for periodic testing and certification, obligations of electrical contractors and workers, registration requirements etc.
- (b) General understanding of the effect of electromagnetic fields and electric shock. Causes and prevention of electrical related fire incidents. Electrical accident investigation.
- (c) General understanding of the need and procedures to assure electrical safety at work, it includes but not be limited to the safety precautions for working on low voltage installations, interlocking systems, circuit identification, safety documentations etc.

2. Design and Applications

- (a) General understanding of various types of earthing systems their merits and demerits (e.g. TT, TN-S, TN-C, TN-C-s etc.), in particular the system adopted in Hong Kong. Selection of protective conductors and earth electrode. Calculation of earth fault loop impedance.
- (b) Applications, design principles, principle of operation and characteristics of various types of power transformers and switchgears.
- (c) Applications, design principles, principles of operation, characteristics and starting methods of various types of electrical machines such as synchronous machines, induction machines, a.c. commutation machines, d.c. machines etc.
- (d) Applications, characteristics, sizing and selection of different types of cables/overload lines with due considerations to load factor, diversity factor, power factor, voltage drop and maximum demand of the installation.
- (e) Factors affecting the design of substations, main switchroom, transformer room and emergency generator room such as clearance space, ventilation requirements, layout of electrical equipments, accessories etc.
- (f) General understanding of circuit arrangement and segregation of different circuit categories.

- (g) General knowledge of the design of power distribution system such as load estimation of an electrical installation, single-line diagram representation of design, sizing and selection of different types of emergency generators to cope with essential load, power factor improvement, Supply Rules of the Power Companies including computation of tariff, conditions of supply etc.
- (h) Operating principles, characteristics and application of different types of protection schemes, protective devices on different types of electrical installation. Co-ordination and discrimination of protective devices. Calculation of fault levels of distribution system for deciding on the ratings of the protective devices.
- (i) Protection of structures against lightning.
- (j) General understanding of the affects caused by non-linear loads in the power system and methods of improvement.
- (k) Illumination level calculations and application of different types of lighting equipment.
- (l) Requirements for installations under adverse conditions such as the presence of water or high humidity, presence of corrosive or polluting substances, installation exposed to fire or explosion, etc.

3. Installation, Testing and Commissioning

- (a) General understanding of wiring installation enclosures such as steel conduit system, steel trunking system, plastic or PVC conduit or trunking, busbar trunking system etc.
- (b) Pre-commissioning and commissioning tests on different types of electrical equipment such as generators, transformers, cables/overhead lines, switchgears, motors, capacitors, protective devices etc.

4. Maintenance

- (a) Corrective maintenance such as fault diagnosis and rectification techniques on electrical installation.
- (b) Preventive maintenance and periodic tests such as functional tests on protective and control devices, wiring insulation resistance test, running test on motors, circuit protectors' tripping and operating mechanism check etc.

Sample Examination Questions for Part A

1. The current rating of a protective device is the current which:
 - (a) it will carry continuously without damages.
 - (b) will cause the device to operate.
 - (c) will cause the device to operate within 30 minutes.
 - (d) is equal to the fusing factor.

2. The rationale of sizing a live conductor based on current carrying consideration is to:
 - (a) protect the equipment supplied by the live conductor.
 - (b) protect the live conductor itself.
 - (c) protect the insulation of the live conductor from excessive temperature.
 - (d) protect the system from earth fault.

3. The characteristics of overcurrent IDMT relay normally used in Hong Kong to protect the low voltage main incoming circuit breaker is of:
 - (a) standard type.
 - (b) very inverse type.
 - (c) extremely inverse type.
 - (d) any of the above.

4. A circuit protective conductor is mainly used to:
 - (a) bond the exposed conductive parts to the extraneous conductive parts.
 - (b) connect between the exposed conductive parts.
 - (c) bond between the extraneous conductive parts when one of the parts is earthed.
 - (d) connect the exposed conductive parts of equipment to the main earthing terminal.

5. For Class 1 equipment, protection against electric shock depends on:
 - (a) single insulation.
 - (b) double insulation.
 - (c) single insulation and equipotential bonding.
 - (d) single insulation and connection of exposed conductive parts to main earthing terminal.

6. A low voltage is a voltage
- (a) not exceeding 220 V root mean square (r.m.s.) alternating current (a.c.) but exceeding extra low voltage.
 - (b) not exceeding 380 V r.m.s. a.c. but exceeding extra low voltage.
 - (c) not exceeding 1000 V r.m.s. a.c. but exceeding extra low voltage.
 - (d) not exceeding 3750 V r.m.s. a.c. but exceeding extra low voltage.
7. Overload current is:
- (i) an abnormal current caused by insulation breakdown.
 - (ii) an abnormal current caused by current flowing from live conductor to earth.
 - (iii) an abnormal current occurring in a circuit which is electrically short-circuited.
 - (iv) an abnormal current flowing from the live conductor to the protective conductor.
- (a) all of the above
 - (b) (iv) only
 - (c) (i) and (ii)
 - (a) none of the above
8. The protective conductors used for circuit protection against earth leakage faults cannot take the form of:
- (i) a bare copper wire in parallel run with the cable.
 - (ii) the outer portion of the metallic conduit.
 - (iii) the steel wire armour of armoured cable.
 - (iv) the outer portion of the Polyvinylchloride (PVC) conduit.
 - (v) a bare copper wire connected to the water pipe inside a domestic flat.
- (a) (i) and (v)
 - (b) (iv) and (v)
 - (c) (i), (ii) and (iv)
 - (d) (ii), (iii) and (v)
9. The main advantages of a single-phase shaded-pole induction motor are:
- (i) robustness.
 - (ii) can rotate at either direction easily.
 - (iii) high efficiency.
 - (iv) low manufacturing cost compared to split-phase induction motors.
 - (v) low noise level.

- (a) (i) and (iv)
 - (b) (iv) and (v)
 - (c) (i), (ii) and (iii)
 - (d) (ii), (iii) and (iv)
10. The conditions for ensuring discrimination between two fuses connected in series in a circuit are:
- (i) the pre-arcing I^2t of the up-stream fuse is not exceeded by the total let-through I^2t of the down-stream fuse in series with it.
 - (ii) the up-stream fuse should be a slow blowing fuse whereas the down-stream fuse is a quick blow fuse.
 - (iii) the down-stream fuse must blow within 0.2 s when current equals to 4 times or higher of the current rating of the entire system flow.
- (a) all of the above
 - (b) (i) only
 - (c) (ii) only
 - (d) (iii) only
11. The correct test sequence for an electrical installation after completion and before energization of the following is:
- (i) insulation resistance.
 - (ii) polarity.
 - (iii) continuity of ring final circuit conductors.
 - (iv) continuity of protective conductors, including main and supplementary equipotential bonding.
- (a) (i), (ii), (iii), (iv)
 - (b) (ii), (iv), (i), (iii)
 - (c) (iii), (iv), (i), (ii)
 - (d) (iv), (iii), (i), (ii)
12. In estimating the size of conductor it is common to limit the current density to below certain values. This implies that:
- (a) the copper loss per unit surface area of the conductor are below a certain limit.
 - (b) the copper loss per unit volume of the conductor are below a certain limit.
 - (c) the total power loss per unit surface area of the conductor are below a certain limit.
 - (d) the total power loss per unit volume of the conductor are below a certain limit.

13. The output torque of a 3-phase induction motor is proportional to
- (i) motor speed.
 - (ii) magnetic flux set up by the stator and linking with rotor conductors.
 - (iii) rotor current.
 - (iv) stator current.
 - (v) input power.
- (a) (ii) and (iii)
 - (b) (iii) and (v)
 - (c) (i), (ii) and (iv)
 - (d) (ii), (iii) and (v)
14. Induction motors can have a self-starting torque if
- (i) there are more than one phase winding.
 - (ii) the currents flowing in the different phases must have different magnitudes.
 - (iii) the currents flowing in the different phases must not be cophasal.
 - (iv) there must be a centrifugal switch to cut off the auxiliary winding.
 - (v) the phase sequence must be correct.
- (a) all of the above
 - (b) (i) and (iii)
 - (c) (i), (ii) and (v)
 - (d) (i), (iv) and (v)
15. Two transformers of different ratings and operating in parallel can be arranged to share the loadings in accordance to their ratings if
- (a) the ohmic internal impedance of both transformers are the same.
 - (b) the per unit internal impedance of both transformers are the same.
 - (c) an equalising bar is connected in each of the output phases.
 - (d) both are made by the same manufacturer.
16. The temperature-rise of tungsten filament lamps depend on:
- (i) the positioning of the lamps (whether vertically up/downward, horizontal or inclined at an angle).
 - (ii) whether there are harmonics in the supply current even if the r.m.s. value of the currents are the same.
 - (iii) whether there are harmonics in the supply voltage even if the r.m.s. value of the voltages are the same.

- (a) (i) only
 - (b) (ii) only
 - (c) (iii) only
 - (d) none of the above
17. Induction motors with a larger pole number is generally larger than a motor with smaller pole number of the same power rating because:
- (i) the output torque of the motor depends on the motor size.
 - (ii) a heavy motor could damp out the low frequency vibration much more readily.
 - (iii) motors with a larger pole number have a higher magnetic flux per pole.
 - (iv) motors with a larger pole number need more space for the additional windings.
- (a) all of the above
 - (b) (i) only
 - (c) (iv) only
 - (d) (i), (ii) and (iv)
18. The advantages of a deep bar induction motor over a standard induction motor are:
- (i) low starting current.
 - (ii) high starting torque.
 - (iii) lower cost.
 - (iv) easy maintenance.
 - (v) more stable operating point.
- (a) all of the above
 - (b) (i) and (ii)
 - (c) (i) and (v)
 - (d) (ii) and (iv)
19. The protective devices and the earthing arrangements for circuits (except separated extra-low voltage (SELV)) in a typical domestic bath room should
- (a) provide earth-fault disconnection times of less than 5 s.
 - (b) provide earth-fault disconnection times of less than 5 s, and current ratings of less than or equal to 5 A.
 - (c) provide earth-fault disconnection times of less than 0.4 s.
 - (d) provide earth-fault disconnection times of less than 0.4 s, and current ratings of less than or equal to 13 A.
20. For an electric stove of a kitchen that has four cooking plates and its total current rating is

20A, which of the following points are correct?

- (i) It should be protected by a 30 mA residual current device (RCD).
 - (ii) It should be fed from an exclusive radial final circuit.
 - (iii) It should be controlled by a double pole switch.
 - (iv) Its control switch should be placed within 2 m of its location.
-
- (a) all of the above
 - (b) (i), (ii) and (iii)
 - (c) (i), (ii) and (iv)
 - (d) (ii), (iii) and (iv)

21. According to BS6651, for large building structure over 20 m high, the recommended number of down conductors in the lightning protection systems is:

- (a) one per 10 m of the perimeter of the building.
- (b) one per 20 m of the perimeter of the building.
- (c) one per 10 m² of the roof area.
- (d) one per 20 m² of the roof area.

22. For a circuit protected by a fuse to BS 88 Part 2, which of the following is/are true for the relationship among, the nominal current rating of the protective device of the circuit (I_n), the design current of the circuit (I_b), the lowest current carrying capacities of any conductor in the circuit (I_t):

- (i) $I_n \geq I_b$
 - (ii) $I_b \geq I_t$
 - (iii) $I_t \geq I_n$
 - (iv) $I_b \geq I_n$
-
- (a) (i) only
 - (b) (i) and (ii)
 - (c) (i) and (iii)
 - (d) (ii) and (iii)

23. In the insulation resistance test of a 220V installation, which of the following statements are true for the phase-to-phase test:

- (i) the insulation resistance should not be less than 500 k Ω .
- (ii) the testing voltage should be 1000 V.
- (iii) solid state light dimmers should be isolated.

- (iv) during the test, a large installation may be divided into sections with groups of outlets, provided that each group contains not less than 100 outlets.
 - (a) (i) and (ii)
 - (b) (i) and (iii)
 - (c) (ii) and (iii)
 - (d) (ii) and (iv)
24. When a cable runs across an expansion joint of the structure of a building,
- (a) the cable should be marked with a colour code.
 - (b) the cable should form into a loop.
 - (c) the cable should be installed in a conduit.
 - (d) its enclosure should be sealed with internal fire-resistant barrier.
25. According to the Code of Practice for the Electricity (Wiring) Regulations, rigid PVC conduits or trunking should not be used where the expected normal working temperature may exceed
- (a) 40 °C.
 - (b) 60 °C.
 - (c) 80 °C.
 - (d) 100 °C.
26. Which one of the following are effective methods to avoid/reduce the effect of heat from external heat sources to a cable?
- (i) installing a thermal shielding.
 - (ii) increasing the separation distance between the cable and the source.
 - (iii) reducing the effective current carrying capacity of the cable.
 - (iv) grouping more number of cables in the same enclosure.
- (a) (i) and (ii)
 - (b) (ii) and (iii)
 - (c) (iii) and (iv)
 - (d) (i), (ii) and (iii)
27. The internal radius of conduit bend for conduits of size up to 32mm should be at least:
- (a) 2 times of the inside diameter of the conduit.
 - (b) 2 times of the outside diameter of the conduit.

- (c) 4 times of the inside diameter of the conduit.
- (d) 4 times of the outside diameter of the conduit.
28. Which of the following recommendation(s) on illumination is(are) reasonable ?
- (i) 50 lux at floor level of a main switch room.
- (ii) 120 lux on the vertical surfaces of equipment in a main switch room.
- (iii) 1200 lux on working plane in a security control room with Closed Circuit Television (CCTV).
- (a) all of the above
- (b) (i) only
- (c) (ii) only
- (d) (iii) only
29. Which of the following point(s) is(are) merits of metal-halide (MBI) lamp over fluorescent tube ?
- (i) Wider and higher rated power range.
- (ii) Higher efficacy.
- (iii) Higher general colour rendering index.
- (iv) Shorter start-up (ignition) time.
- (v) Shorter re-strike time.
- (a) (ii) only.
- (b) (iii) only.
- (c) (i), (ii) and (iii)
- (d) (iii), (iv) and (v)
30. Which of the following is(are) measure(s) to cope with harmonic currents in the 3-phase 4-wire circuits of a large bank of discharge lamps ?
- (i) Connect power factor correction capacitors across the supply terminals.
- (ii) De-rate the current carrying capacity of the cables used.
- (iii) Make sure the neutral conductor is at least the same size as the phase conductor.
- (a) (i) and (ii)
- (b) (i) and (iii)
- (c) (ii) and (iii)
- (d) none of the above

Sample Examination Questions for Part B

- Q1 (a) According to earthing arrangement classification of IEE Wiring Regulations, describe the type of earthing arrangements normally applied in Hong Kong under various situations, as required by the Code of Practice for the Electricity (Wiring) Regulations. What considerations should be paid to the earthing arrangement during the design of an electrical installation?
- (b) A 220 V, 100 A circuit has an earth fault loop impedance of 1Ω . Suggest a protection scheme against earth fault. State your reasons, assumptions and criteria.
- (c) Give the reasons for high normal earth leakage current may exist in some electrical equipment (such as computer workstation). What suggestions can be given or special considerations should be allowed in connecting this equipment (particularly in the earthing aspect)?

Q2 A consumer is supplied at 380V 3 phase from a 11 kV substation through a 1500 kVA 11kV/380V transformer and a 380V cable as shown in Fig. Q2. An overcurrent relay supplied through a 3000/5 C.T. is installed at the low voltage side of the transformer to protect the cable and the consumer. The fault level of the 11kV substation is 250 MVA. The impedance of the transformer and the 380V cable are shown in Fig. Q2.

- i) Calculate the maximum fault current which the relay will be expected to measure for any type of fault in the 380V system.
- ii) Determine the overcurrent plug setting (PS) of the overcurrent relay if the maximum load current which the transformer can tolerate is 1.2 times full load.
- iii) Determine the time multiplier setting (TMS) of the overcurrent relay if the relay operating time cannot be longer than 0.6s under maximum fault current conditions.
- iv) After the PS and TMS have been determined, calculate the relay operating time for a single phase to earth fault in the 380V consumer switchboard.

The relay rating is 5A. The PS range of the overcurrent relay is from 50% to 200% in steps of 25%. The TMS range is from 0.1 to 1.0 in steps of 0.1. The operating time of the overcurrent relay can be calculated from the following formula:

where t = operating time of the relay in second

I_f = fault current through the relay

I_{set} = current setting of the relay

$$t = (TMS) * \frac{0.14 \text{ sec.}}{\left(\frac{I_f}{I_{set}}\right)^{0.0202} - 1}$$

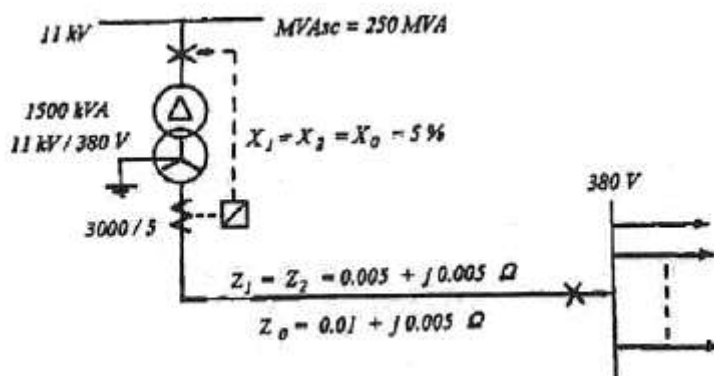


Fig. Q2

- Q3 (a) Four similar single-phase circuits each having $I_b = 13 \text{ A}$ are to be wired in single-core 70°C polyvinylchloride (PVC)-insulated PVC sheathed cables to BS 6004 with copper conductors. The cables are enclosed in conduits totally surrounded by a 150 mm long thermally insulating materials.

The ambient temperature is expected to be 45°C and each circuit is protected by a 20 A miniature circuit breaker (MCB) against both overload and short circuit. The supply voltage is 220 V, single-phase.

- (i) Based on the ampacity consideration alone, what is the minimum cross-sectional area of the conductor that can be used?
 - (ii) If the circuit run is 10 m and the voltage drop at the MCB board is 2%, determine if the cable size is adequate from the voltage drop considerations.
- (b) For a three-bedroom flat with the following data:
- 12 nos. of lighting points in 2 nos. of 5A lighting circuits.
 - 1 no. of 20 A final socket outlet circuit serving the kitchen individually (in accordance to Code 6E of the Code of Practice for the Electricity (Wiring) Regulations (COP))
 - 1 no. of 20 A final socket outlet circuit serving the living room, dining room, master bedroom, bedrooms and other area (in accordance to Code 6E of COP)
 - 1 no. of 20 A final circuit serving an air-conditioner in the living room with full-load current of 15 A (in accordance to Code 6E of COP)
 - 2 nos. of 20 A final radial circuits serving an air-conditioner in the bedrooms, dining room and master bedroom, each with a full-load current of 8 A (in accordance to Code 6E of COP)

Assume 220 V single-phase supply and allow for 10 % spare capacity, find:

- (i) the maximum demand for the flat;
- (ii) the current rating of the single-phase main switch.

Q4 The single line diagram represents part of the main electrical distribution of an industrial building in Hong Kong. The transformers are supplied and installed by the power company.

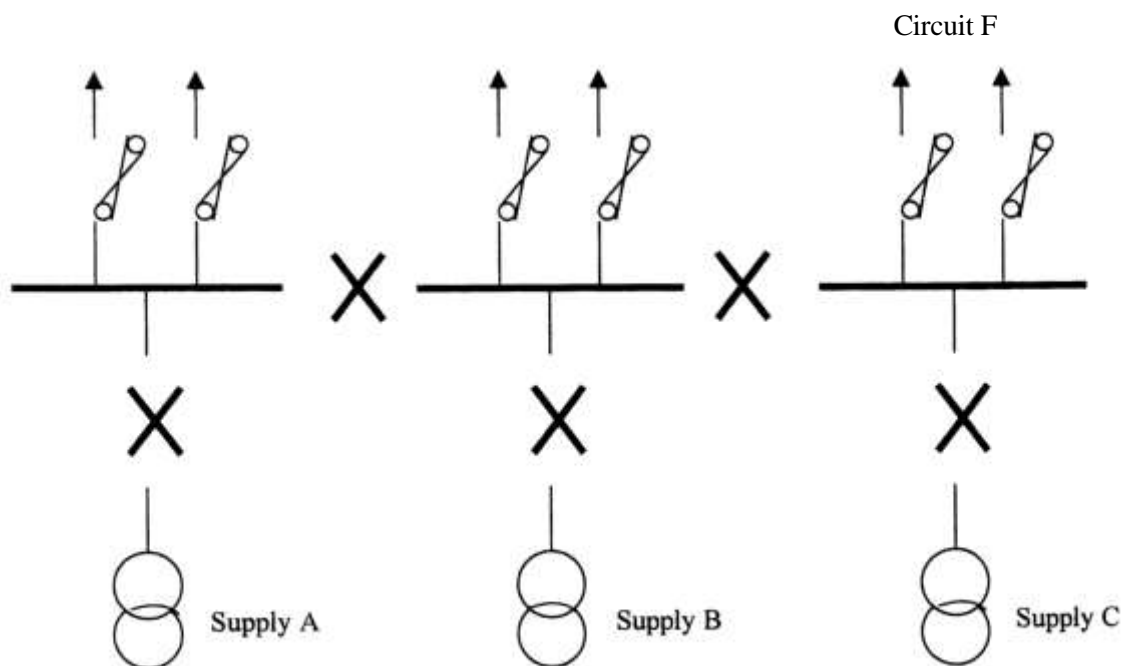


Fig. Q4

- Advise on the requirements, with supporting reasons in brief, for selecting, installing and interlocking the two section switches in the above system.
- Consider that the Circuit F is for fire services equipment and emergency supply that are also connected to a standby generator of the building. Show schematically how the changeover should be arranged.
- State, with supporting explanation in brief, the minimum number of earth fault relays that is sufficient to protect the whole system including the standby generator circuit. Indicate their positions in a diagram.
- Draw a current transformer (C.T.) connection diagram of a 3-phase earth fault relay. Based on this diagram, illustrate its operation principle.

Q5 (a) With the aid of a practical connection diagram, explain how one could inject direct current (d.c.) into the windings of induction motors in order to inject rated losses into the motor without any shaft load imposed onto the motor. What are the limitations of your proposed scheme?

(b) At its rated speed of 13000 rev/min a permanent magnet dynamometer delivers its rated armature current of 2 A into a 10Ω external resistor. When the external resistor is short circuited, the dynamometer delivers 5 A at the same rated field current and 10000 rev/min.

Is this dynamometer suitable for testing a 4-pole 50 Hz induction motor which demands a peak torque of 0.018 Nm? Give a logical explanation to your answer.

(c) As there is no suitable dynamometer to load up a 100 kW, 50 Hz, 4-pole induction motor in order to assess the thermal characteristics of the motor, it is recommended that the motor should be operated with two power supplies, one at 48 Hz and one at 50 Hz as shown in Fig. Q5. By referring to a sketch of the torque/speed characteristics of the machine in response to 50 Hz and 48 Hz on the same diagram, give a brief explanation in simple words to describe the operating principles of this winding connection. Hence deduce the order of magnitudes of these two voltages ?

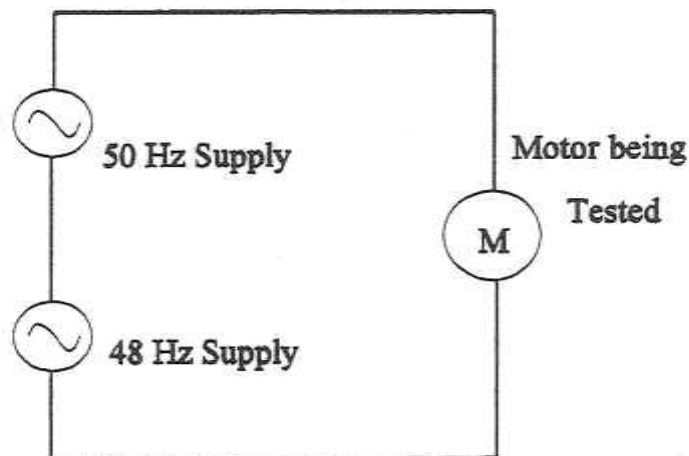


Fig. Q5

- Q6 (a) A building in Hong Kong is to be equipped with a 1500 kVA, 11000/380 V transformer for supplying electricity. The present consumption without any power factor correction capacitor bank is 1200 kVA and 800 kW. Given that 1 kVAr of capacitor bank costs \$620 and the depreciation is 8%, find the most economical power factor of the system and hence the kVAr required to achieve such operating condition. Given that the demand charge for each kVA is HK\$ 117.

(b)

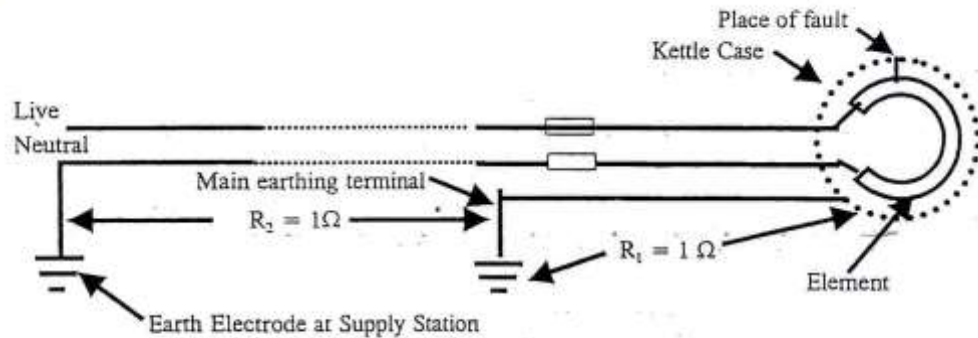


Fig. Q6

On a 2 kW kettle connected to a 220 V supply, a fault to earth occurs, through the earthed metal casing of the appliance, at a point a quarter along the length of its heating element from the 'live' terminal, as shown in Fig. Q6. The kettle is protected by a 15 A fuse which is designed to blow at a current of 47 A in one second, 33 A in ten seconds, or 28 A in one minute.

Assuming that the resistance of the earth continuity path between the kettle and the main earthing terminal provided by the electricity supplier (R_1) is $1\ \Omega$ and the resistance between the earthing terminal and the earth electrode at the supply station (R_2) is also $1\ \Omega$, ignoring the resistance of the circuit wiring and also that between the heating element and the point of fault contact with the earth casing :

- (i) calculate the fault current which will flow;
- (ii) calculate the voltage between the metal casing of the kettle and the earth electrode at the supply station, and further;
- (iii) elaborate whether the fuse or the heating element will burn out in your opinion.

- Q7 (a) Give the definition of total harmonic distortion (THD) of a current waveform.

Sketch a typical current waveform such that it contains only odd harmonics but not even harmonics, and state the main special features in that waveform.

- (b) To achieve better energy efficiency, many buildings have been changing most or all filament lighting systems to discharge lighting systems with electronic ballasts. State the positive and negative impacts of this change on the electrical installations of buildings and propose measures to rectify these adverse impacts.

- (c) Design a general lighting system for a classroom with a target illuminance ≥ 600 lux on a working plane which is 0.9 m above floor. Relevant data are listed below:

- Dimensions of the room: 5 m (L) x 10 m (W) x 3.4 m (H)
- Location of the blackboard: at the centre of the 5 m long wall, it is a full height blackboard.
- Reflectance: ceiling: 0.7; wall 0.5; floor cavity: 0.2
- Total light loss factor is estimated to be 0.78.
- Luminaire (model SDW236) are surface mounted on the ceiling.
- In each luminaire, two fluorescent tubes are installed, with 2500 average initial lumen per tube.
- Photometric data of the luminaire are provided (Remarks A).

- (i) Sketch the layout of your design, including your suggested orientation of the luminaire. You are NOT required to make a detailed calculation on glare index. However, you have to observe the relative values between crosswise and endwise glare indices.

- (ii) What will be the expected illumination level on the floor of the classroom under your design?

- (iii) If all luminaire are turn off except the one nearest to the blackboard, what is the illumination level at the centre of the blackboard?

Remarks A: Luminaire data are provided as an appendix of the appropriate examination paper.

Q8 Refer to the diagram Fig. Q8, the load has its phase conductors connected to distribution board P and its neutral conductor to distribution board Q.

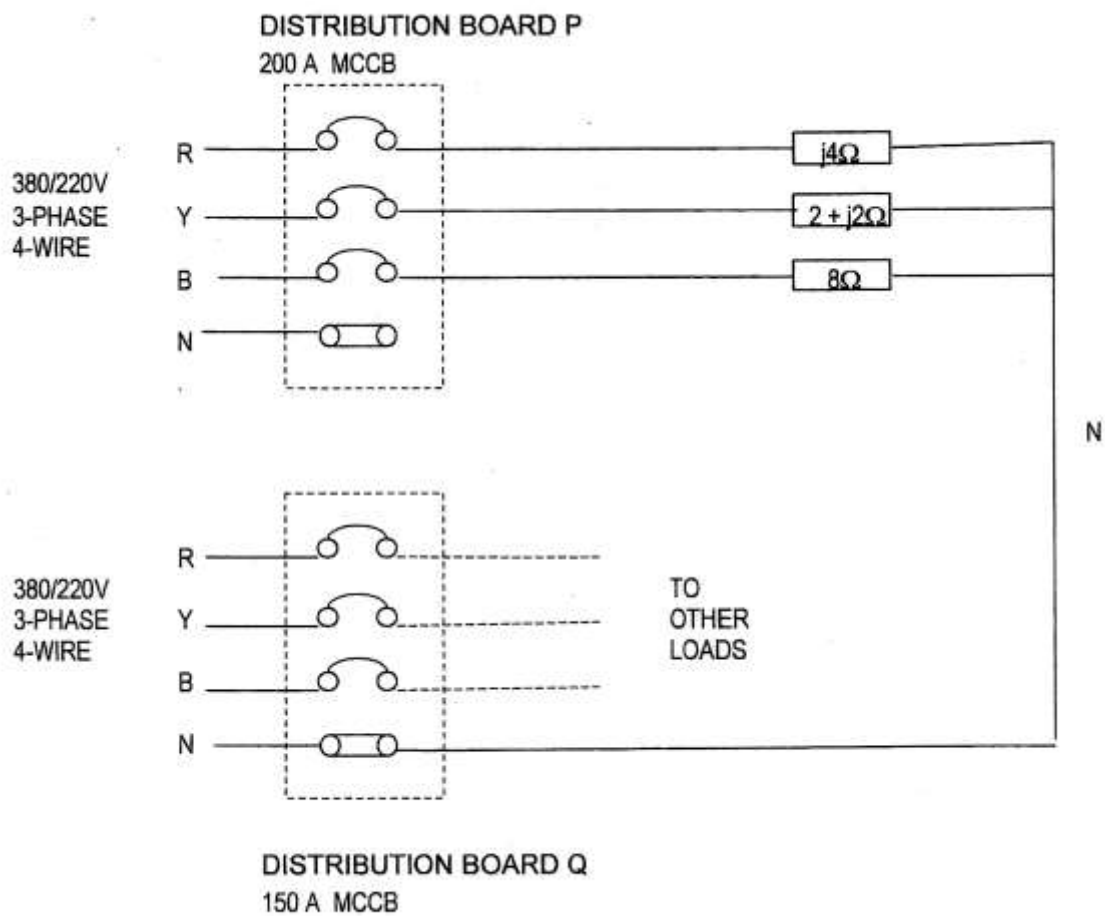


Fig. Q8

- a) Calculate the currents in the load.
- b) Using Millman's Theorem or otherwise, determine the voltage of the neutral when the neutral link of the 150A distribution board Q has been isolated.
- c) Point out the problems and potential dangers of this connection.
- d) If both distribution boards are protected by RCDs, describe what will happen?

C級電業工程人員註冊考試大綱

參考資料： 電力(線路)規例工作守則、英國電機工程師學會佈線規例、本地供電規則、電機工程手冊,以及有關設計、安裝、校驗及維修電力裝置的國際標準及刊物。

1. 一般知識

- a) 熟悉有關的本地法規及電力條例，例如有關進行定期測試及簽發證明書的規定、電業承辦商及電業工程人員的責任及註冊規定等。
- b) 對電磁場及電擊的影響、電力所引起火警的成因和預防方法，以及調查電力意外的一般認識。
- c) 對電力安全，例如進行低壓電力裝置工程時須採取的預防措施、連鎖系統、作出識別及擬備安全文件等的一般認識。

2. 設計與應用

- a) 對各種接地系統，特別是本地的接地系統，及其優點、缺點的一般認識(例如：TT, TN-S, TN-C, TN-C-S 等)；適當保護導體及接地極的選擇，以及接地故障環路阻抗的計算。
- b) 各種電力變壓器及開關設備的應用、設計原理、操作原理及特性。
- c) 各種電機，例如同步電機、感應電機、交流電整流電機、直流電電機等的應用、設計原理、操作原理、特性及起動方法。
- d) 各種電纜/架空電纜的應用、特性、尺寸定位和選擇，必須適當考慮有關負載系數、不等率、功率因數、電壓降及裝置的最大需求量等因數。
- e) 影響設計電力分站、主開關房、變壓器室及緊急發電室的因素，例如間隙空間、通風設備、電力設備的配置和附件等。
- f) 對各類電路的電路安排和分隔的一般認識。
- g) 對以下各項的一般認識：配電系統,例如電力裝置的負荷估計；設計的單線圖表示法；用以應付基本負荷的各種緊急發電機的尺寸定位和選擇；功率因數的提升；電力公司的供電規則，包括計算電費、供電條件等。
- h) 不同種類電力裝置的各種保護裝置的操作原理、特性和應用；各種保護裝置的協調和區別；配電系統故障率的計算，以決定保護系統及裝置的額定值。

- i) 裝置結構的避雷保護。
- j) 由非線性負荷對供電系統所產生的影響及有關改善方法的一般認識。
- k) 照明程度的計算及各種照明設備的應用。
- l) 有關在不利條件下，例如存有水分或濕度過高、存有腐蝕性或污染物質、容易發生火警或爆炸的情況下，安裝電力裝置的規定。

3. 安裝、測試和校驗

- a) 對線路裝置外殼，例如鋼製導管系統、鋼製線槽系統、塑膠或聚氯乙烯導管或線槽、匯流排線槽系統等的一般認識。
- b) 各種電力設備，例如發電機、變壓器、電纜/架空電纜、開關設備、馬達、電容器、保護裝置等的校驗前及校驗測試。

4. 維修

- a) 電力裝置的故障檢修，例如故障診斷及修理方法。
- b) 預防性檢修及定期測試，例如功能檢查、線路絕緣電阻測試、馬達的運轉測試、線路保護器的斷路及操作機械裝置的檢查等。

甲部試題樣本

1. 過流保護器件的電流額定值是
 - a) 該器件能持久負載而不受損的電流值。
 - b) 引致該器件操作的電流值。
 - c) 引致該器件在 30 分鐘內操作的電流值。
 - d) 等同於熔斷因數。

2. 當以載流量的考慮來決定帶電導體的大小時，基本理由是要
 - a) 保護由帶電導體供電的器具。
 - b) 保護帶電導體本身。
 - c) 防止帶電導體的絕緣體達致太高溫度。
 - d) 防止系統的接地故障。

3. 在香港，用以保護低壓側總開關掣的反時限最小定限時繼電器(IDMT)的特性一般是
 - a) 標準類。
 - b) 非常反時限類。
 - c) 極端反時限類。
 - d) 上述任何一類。

4. 電路保護導體主要是用來
 - a) 接駁外露非帶電金屬部分至非裝置電氣金屬部分。
 - b) 作外露非帶電金屬部分間的連接。
 - c) 接駁於非裝置電氣金屬部分間，當其中之一是接地的。
 - d) 連接器具的外露非帶電金屬部分至總接地終端。

5. 第一級(Class 1) 電氣器具的防止電擊是依賴
 - a) 單層絕緣。
 - b) 雙重絕緣。
 - c) 單層絕緣及等電位接駁。
 - d) 單層絕緣及連接外露非帶電金屬部分至總接地終端。

6. 交流低壓是指在正常情況下，導體與導體間的電壓
 - a) 不超逾 220 伏特均方根(V_{rms})，但超逾特低壓的交流電壓。

- b) 不超過 380 伏特均方根(V_{rms})，但超過特低壓的交流電壓。
- c) 不超過 1000 伏特均方根(V_{rms})，但超過特低壓的交流電壓。
- d) 不超過 3750 伏特均方根(V_{rms})，但超過特低壓的交流電壓。

7. 過載電流是指

- (i) 由絕緣體崩潰所引致的不正常電流。
 - (ii) 由相導體流向接地電流所引致的不正常電流。
 - (iii) 電路中的電氣短路內所出現的不正常電流。
 - (iv) 由相導體流向保護導體的不正常電流。
- a) 全部都是
 - b) 祇是(iv)
 - c) (i)及(ii)
 - d) 全部都不是

8. 用來作對地漏電故障電路保護的保護導體不能是

- (i) 與電纜並行的裸銅線。
 - (ii) 金屬導管的外部。
 - (iii) 裝甲電纜的鋼支裝甲。
 - (iv) 聚氯乙烯(PVC)導管的外部。
 - (v) 連接至住宅水管的裸銅線。
- a) (i) 及 (v)
 - b) (iv) 及 (v)
 - c) (i)、(ii) 及 (iv)
 - d) (ii)、(iii) 及 (v)

9. 單相遮極感應電動機的主要優點是

- (i) 扎實。
 - (ii) 容易使它反方向運轉。
 - (iii) 高效率。
 - (iv) 製造成本較分相感應電動機低。
 - (v) 低噪音。
- a) (i) 及 (iv)
 - b) (iv) 及 (v)
 - c) (i)、(ii) 及 (iii)
 - d) (ii)、(iii) 及 (iv)

10. 在一電路上，兩串聯接駁的熔斷器能達致區別運作的條件是
- (i) 上游熔斷器產生電弧前的 I^2t 不能超逾下游串聯熔斷器總通泄能量的 I^2t 。
 - (ii) 上游熔斷器應為一慢操作熔斷器，而下游熔斷器則應為一快操作熔斷器。
 - (iii) 當電流是整個系統的電流額定值的四倍或以上時，下游熔斷器必須能在 0.2 秒(s)內操作。
- a) 以上全部
 - b) 祇有(i)
 - c) 祇有(ii)
 - d) 祇有(iii)
11. 電力裝置完工後在通電前，正確測試步驟的次序應是
- (i) 絕緣電阻
 - (ii) 極性
 - (iii) 環形最終電路的電氣連續性
 - (iv) 電路保護導體的電氣連續性，包括主等電位接駁及輔助接駁
- a) (i) ， (ii) ， (iii) ， (iv)
 - b) (ii) ， (iv) ， (i) ， (iii)
 - c) (iii) ， (iv) ， (i) ， (ii)
 - d) (iv) ， (iii) ， (i) ， (ii)
12. 當決定導體的大小時，通常會限制電流密度低於某一數值，這表示
- a) 導體上每個單位表面面積的銅耗須低於某一數值。
 - b) 導體上每個單位體積的銅耗須低於某一數值。
 - c) 導體上每個單位表面面積的總能量損耗須低於某一數值。
 - d) 導體上每個單位體積的總能量損耗須低於某一數值。
13. 三相感應電動機能的輸出轉矩，是跟下列那些參數成正比的:
- (i) 電動機的轉速
 - (ii) 由定子放出而連繫到轉子的磁通量
 - (iii) 轉子的電流
 - (iv) 定子的電流
 - (v) 輸入功率
- a) (ii) 及 (iii)
 - b) (iii) 及 (v)
 - c) (i) 、(ii) 及 (iv)

d) (ii) 、(iii) 及 (v)

14. 在下列條件下結合，感應電動機能產生自起動轉矩:

- (i) 有多於一相線組。
- (ii) 不同相的電流必須有不同量值。
- (iii) 不同相的電流必須不是同相位。
- (iv) 必須有一離心式開關掣去切斷輔助線組。
- (v) 相序必須正確。

- a) 以上全部
- b) (i) 及 (iii)
- c) (i) 、(ii) 及 (v)
- d) (i) 、(iv) 及 (v)

15. 兩台不同額定值的變壓器並聯運作，在下列那一情況下，各自分擔的負荷是會與額定值成正比。

- a) 兩台變壓器的內阻抗數字值是相同
- b) 兩台變壓器的內阻抗百分率是相同
- c) 輸出的每一相都有一均衡槓連接
- d) 兩台變壓器是由同一生產商製造

16. 鎢絲燈的溫升取決於:

- (i) 燈的安裝位置(垂直上下、水平或傾斜)。
- (ii) 電源電流的諧波量大小，即使電流的均方根值一樣。
- (iii) 電源電壓的諧波量大小，即使電壓的均方根值一樣。

- a) 祇有 (i)
- b) 祇有 (ii)
- c) 祇有 (iii)
- d) 全部都不是

17. 極數較多的感應電動機的體積，一般比同一額定功率但極數較少的感應電動機的體積大，因為:

- (i) 電動機的輸出轉矩取決於電動機的體積。
- (ii) 重的電動機能較易減低低頻顫動。
- (iii) 極數較多的電動機，每極有較高的磁通量。
- (iv) 極數較多的電動機需為增加的線組提供較多空間。

- a) 以上全部
- b) 祇有 (i)
- c) 祇有 (iv)
- d) (i)、(ii) 及 (iv)

18. 深槓式的感應電動機比標準的感應電動機優勝的地方是:

- (i) 低起動電流。
- (ii) 高起動轉矩。
- (iii) 低製造成本。
- (iv) 維修容易。
- (v) 較穩定的運作點

- a) 以上全部
- b) (i) 及 (ii)
- c) (i) 及 (v)
- d) (ii) 及 (iv)

19. 住宅浴室內，電路(除分隔特低壓(SELV)外)中的保護器件及接地安排應使

- a) 接地故障時電流切斷時間少於 5 秒(sec)。
- b) 接地故障時電流切斷時間少於 5 秒(sec)，及電流額定值不超逾或等於 5 安培(A)。
- c) 故障時電流切斷時間少於 0.4 秒(sec)。
- d) 接地故障時電流切斷時間少於 0.4 秒(sec)，及電流額定值不超逾或等於 13 安培(A)。

20. 住宅廚房內有一電爐，電爐有四個爐面，總電流額定值是 20 安培(A)，下列那點是正確的？

- (i) 電爐應由一個 30 毫安(mA)漏電式斷路器 (RCD) 保護。
- (ii) 電爐應由一專用的放射式最終電路供電。
- (iii) 電爐應由一雙極開關掣控制。
- (iv) 開關掣應安裝於電爐的 2 米(m) 範圍內

- a) 以上全部
- b) (i)、(ii) 及 (iii)
- c) (i)、(ii) 及 (iv)
- d) (ii)、(iii) 及 (iv)

21. 根據英國標準 BS6651 所推介，對於高度超逾 20 米(m)的大型建築物，其防雷系統內防雷下引線的數目是
- a) 沿建築物周界，每 10 米(m)長度有一根。
 - b) 沿建築物周界，每 20 米(m)長度有一根。
 - c) 在建築物頂部，每 10 平方米(m²)面積有一根。
 - d) 在建築物頂部，每 20 平方米(m²)面積有一根。
22. 對於由符合英國標準 BS 88 第 2 部的熔斷器保護的電路，在下列那個關於保護器件的標稱電流額定值(I_n)、電路的設計電流(I_b)及電路上任何一導體的最少載流量(I_t) 的關係是正確的：
- (i) $I_n \geq I_b$
 - (ii) $I_b \geq I_t$
 - (iii) $I_t \geq I_n$
 - (iv) $I_b \geq I_n$
- a) 祇有 (i)
 - b) (i) 及 (ii)
 - c) (i) 及 (iii)
 - d) (ii) 及 (iii)
23. 在 220 伏特(V) 電氣裝置的絕緣電阻測試時，對於相與相的測試，下列那點是正確的？
- (i) 絕緣電阻不應少於 500 千歐姆(k Ω)。
 - (ii) 測試電壓應是 1000 伏特(V)。
 - (iii) 應隔離電子式光暗掣。
 - (iv) 測試時，大型電氣裝置可分為多個部分，但每部分的插座不可少於 100 個。
- a) (i) 及 (ii)
 - b) (i) 及 (iii)
 - c) (ii) 及 (iii)
 - d) (ii) 及 (iv)
24. 當電纜穿過建築物結構內的伸縮縫時，
- a) 電纜應記上顏色碼。
 - b) 電纜應繞成環狀。

- c) 電纜應安裝在導管內。
 - d) 電纜的外殼應用防火障礙物加以密封。
25. 根據【電力(線路)規例工作守則】，當估計的正常工作溫度高於下述數值時，是不可以使用硬性聚氯乙烯(PVC)導管或線槽：
- a) 40 °C。
 - b) 60 °C。
 - c) 80 °C。
 - d) 100 °C。
26. 下列那些方法可有效防止或減低由電纜外的熱源所引致的熱效應：
- (i) 加裝隔熱屏障。
 - (ii) 加大電纜與熱源間的分隔距離。
 - (iii) 減低電纜的有效載流量。
 - (iv) 組合更多數目的電纜於同一外殼內。
- a) 以上全部
 - b) (i) 及 (ii)
 - c) (iii) 及 (iii)
 - d) (ii) 及 (iv)
27. 對少於 32 毫米(mm)的導管，導管彎位的內半徑最少應是：
- a) 導管內直徑的兩倍。
 - b) 導管外直徑的兩倍。
 - c) 導管內直徑的 4 倍。
 - d) 導管外直徑的 4 倍。
28. 下列那項照明度建議是合理的？
- (i) 一間總開關掣房地面的照明度應是 50 勒克斯(lux)
 - (ii) 一間總開關掣房內器具垂直面的照明度應是 120 勒克斯(lux)
 - (v) 一間內有閉路電視(CCTV)的保安室，工作面的照明度應是 1500 勒克斯(lux)
- a) 以上全部
 - b) 祇有 (i)
 - c) 祇有 (ii)
 - d) 祇有 (iii)

29. 下列那項是金屬鹵化物(MBI)燈比熒光燈優越的地方？

- (i) 額定功率範圍較寬及較高
- (ii) 光效較高
- (iii) 一般顯色指數較高
- (iv) 啟動時間較短
- (v) 再啟動時間較短

- a) 祇有 (ii)
- b) 祇有 (iii)
- c) (i)、(ii) 及 (iii)
- d) (iii)、(iv) 及 (v)

30. 下列那方法可應付一大組放電燈於三相四線電路上所產生的諧波？

- (i) 接駁補償功率因數電容器於電源端子上
- (ii) 降低所用電纜的載流量
- (iii) 確保中性導體的大小不小於相導體的大小

- a) (i) 及 (ii)
- b) (i) 及 (iii)
- c) (ii) 及 (iii)
- e) 以上全部都不可

乙部試題樣本

- Q1 (a) 根據「英國電機工程師學會佈線規例」內的接地安排分類法，「電力(線路)規例工作守則」所要求的本港一般電氣裝置在各種情況下，是採取那類接地安排？在設計電氣裝置時又應怎樣考慮接地安排？
- (b) 有一 220 伏特(V)、100 安培(A)的電路,其接地故障環路阻抗為 1 歐姆(Ω)，試為這電路提供一個接地故障防護措施。需說明理由、假設及所需條件。
- (c) 一些電力器具(如計算機工作台)可能會有較高的正常對地漏電電流，試解釋其原因。當連接這些器具，應注意甚麼事項或提供甚麼建議(尤其接地方面)。

Q2 如圖 Q2 所示, 有一 11 千伏(kV)電力分站,經一個 11 千伏(kV)/380 伏特(V)1500 千伏安(kVA)變壓器, 及一束 380 伏特(V)電纜, 為一用戶提供 380 伏特(V)三相電力。為保護電纜及用戶, 在變壓器的低壓側, 經一個 3000/5 電流互感器(CT), 裝設有一過流保護繼電器。那 11 千伏(kV)電力分站的預期故障水平為 250 兆伏安(MVA)。變壓器及電纜的電抗已在圖 Q2 顯示。

- (i) 試算出過流保護繼電器, 在 380 伏特(V)上任何一種故障情況下, 預期所測知的最高故障電流。
- (ii) 若變壓器最高載流量為額定電流的 1.2 倍, 試定出過流保護繼電器上的電流定位(PS)。
- (iii) 若過流保護繼電器的運作時間, 在最高故障電流時, 不能久於 0.6 秒, 試定出過流保護繼電器上的時間倍數定位(TMS)。
- (iv) 當電流定位(PS)及時間倍數定位(TMS)如(ii)及(iii)定下時, 試求出在 380 伏特(V)用戶總開關掣內有一接地故障時, 過流保護繼電器的運作時間。

過流保護繼電器的額定電流為 5 安倍(A)。PS 值可由 50%至 200%, 每級為 25%。TMS 值可由 0.1 至 1.0,每級為 0.1。運作時間可由下列方程算出:

t = 運作時間,單位為秒(sec.)

I_f = 繼電器上的故障電流

I_{set} = 繼電器上的電流定值。

$$t = (TMS) \times \frac{0.14 \text{ sec.}}{\left[\frac{I_f}{I_{set}} \right]^{0.02} - 1}$$

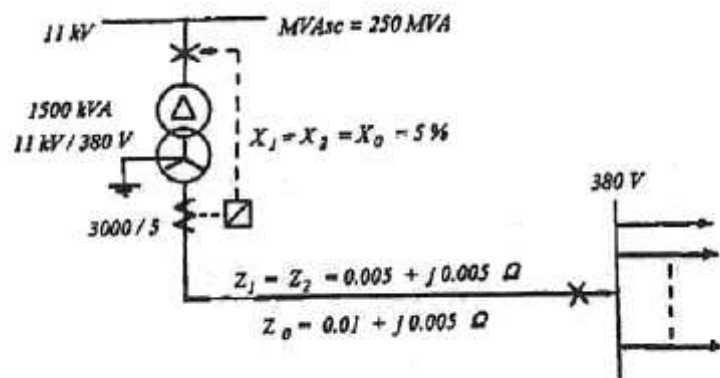


圖 Q2

Q3. (a) 有四個相同的單相電路，每個電路的 $I_b=13$ 安培(A)，電路是使用符合英國標準 BS 6004 無護套的單蕊 70°C 聚氯乙烯(PVC)絕緣銅導體電纜。電纜是安裝在導管內，及完全被長度為 150 毫米(mm)的隔熱物包圍。

環境溫度預計是 45°C，每個電路由一個 20 安培(A)小型斷路器(MCB)保護，以防過載及短路。電源電壓是單相 220 伏特(V)。

- (i) 單以電流量的考慮，所使用電纜的導體截面積最小應是多少？
- (ii) 如果電路的長度是 10 米(m)，而到小型斷路器處的電壓降是 2%。當考慮到總電壓降的要求時，上述求得的電纜大小是否仍然足夠？

(b) 有一個三房住宅單位，詳情如下：

- 有 12 個照明點，每點有 2 個 5 安培(A)照明電路。
- 有 1 個 20 安培(A)最終插座電路，這電路只供電給廚房(根據【電力(線路)規例工作守則】內 6E 部份)。
- 有 1 個 20 安培(A)最終插座電路，這電路供電給客廳、飯廳、主人房、兩睡房及其他地方(根據【電力(線路)規例工作守則】內 6E 部份)。
- 有 1 個 20 安培(A)最終電路，這電路供電給客廳的冷氣機，冷氣機的滿載電流是 15 安培(A) (根據【電力(線路)規例工作守則】內 6E 部份)。
- 有 2 個 20 安培(A)最終放射型電路，這 2 個電路供電給飯廳、主人房、兩睡房內的冷氣機，每一冷氣機的滿載電流是 8 安培(A) (根據【電力(線路)規例工作守則】內 6E 部份)。

假設電源是單相 220 伏特(V)，及容許有 10%的後備容量。試計算出：

- (i) 單位的總電流需求量。
- (ii) 總開關掣的額定值。

Q4 下述的單線圖 Q4 代表香港一幢工業大廈裏主要電氣的分電網的一部分。那變壓器是由電力公司供給和安裝的。

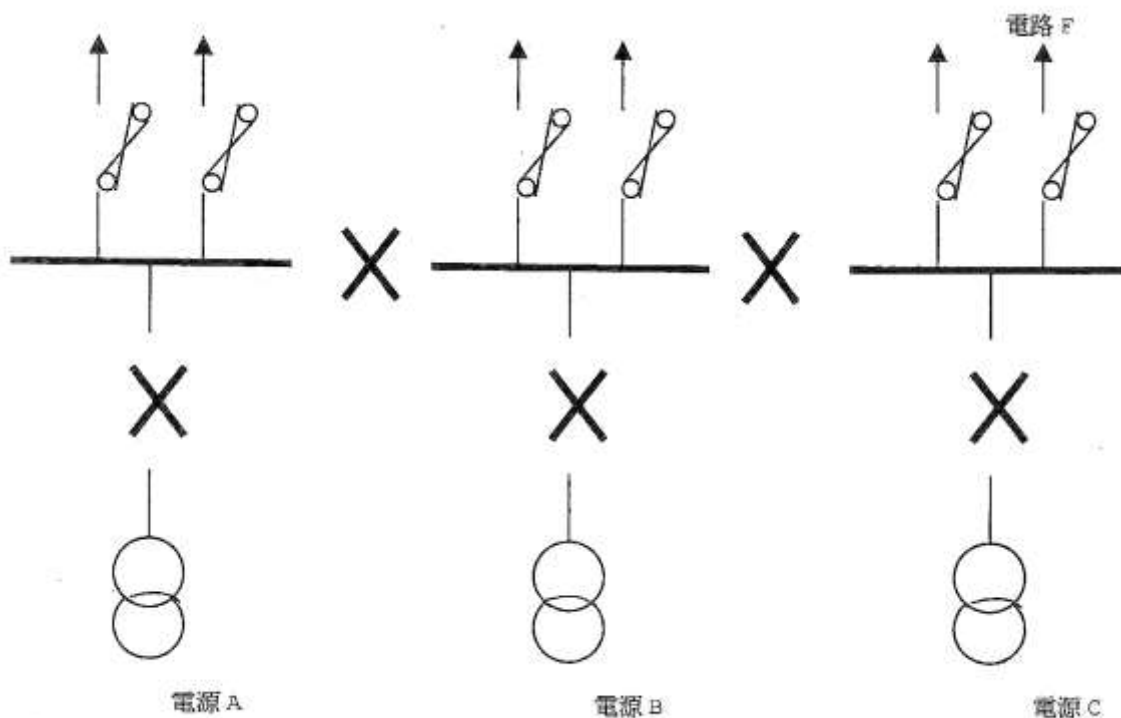


圖 Q4

- 上述系統中的兩個分段開關，在對它們作出挑選、安裝、連鎖設計時，要有什麼要求，試提建議。須有簡短理由來支持你的答案。
- 考慮到電路 F 是供應消防火設備和備用電源，並連接到大廈的備用發電機。試用簡圖來陳述電源轉換是應該怎麼樣安排。
- 試陳述，最少可用多少個接地故障繼電器以充分保護包含備用發電機電路的全部系統。須有簡短理由來支持你的答案，並顯示這些繼電器的在圖裡面的位置。
- 畫出一個圖以顯示三相接地故障繼電器的變流器(CT)的接線方法。並根據這個圖，說明它的運營原理。

- Q5 (a) 試解釋如何將直流電流注入感應電動機的線組，從而在無須加上任何電動機軸心負荷情況下，達致注入額定損耗到電動機裏的目的。答案須輔以實用連接方法圖。你所提議的方案之局限性是什麼？
- (b) 一台永磁式發電機在 13,000 轉/分(rev/min)額定轉速時，輸出 2 安培(A) 額定電樞電流至一個 10 歐姆(Ω)外接電阻。當外接電阻是短路時，在同一場電流額定值及 10,000 轉/分(rev/min)轉速下，發電機輸出 5 安培(A)電流。這發電機是否適合用來測試一台四極、50 赫茲(Hz)的感應電動機，而該感應電動機需要一峰值為 0.018 牛米(Nm) 的轉距。答案須輔以合理解釋。
- (c) 因無合適發電機可用來為一台 100 千瓦(kW) 、四極、50 赫茲(Hz)的感應電動機加上負荷，以評估該感應電動機的熱能特性，現有一提議：如圖 Q5 所示，該電動機須在兩電源下運作，一電源是 48 赫茲(Hz)，另一電源是 50 赫茲(Hz)。先在同一圖內，粗略繪出該電動機分別在 48 赫茲(Hz) 及 50 赫茲(Hz) 電源下的轉距/轉速特性曲線。根據這些特性曲線，簡單解釋這線組連接方法的運作原理，並粗略推斷出這兩電源的電壓的大小。

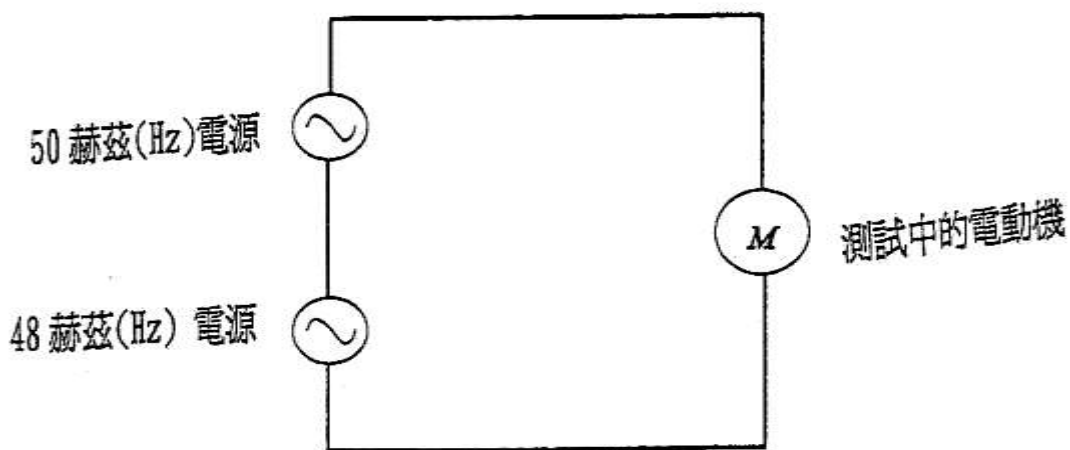


圖 Q5

- Q6 (a) 在香港有一幢樓宇，內有一台 1500 千伏安(kVA) 11,000/380 伏特(V) 變壓器作供電用。現時未有功率因數補償電容組前的總耗電量是 1200 千伏安(kVA) 及 800 千瓦(kW)。電容組的價格已知是每 1 千乏(kVAr)為\$620，折舊率是 8%。試計算出系統的最經濟的功率因數，以及要達致這運行情況所需的千乏(kVAr)。電力需求收費已知是每 1 千伏安(kVA)為\$117。

(b)

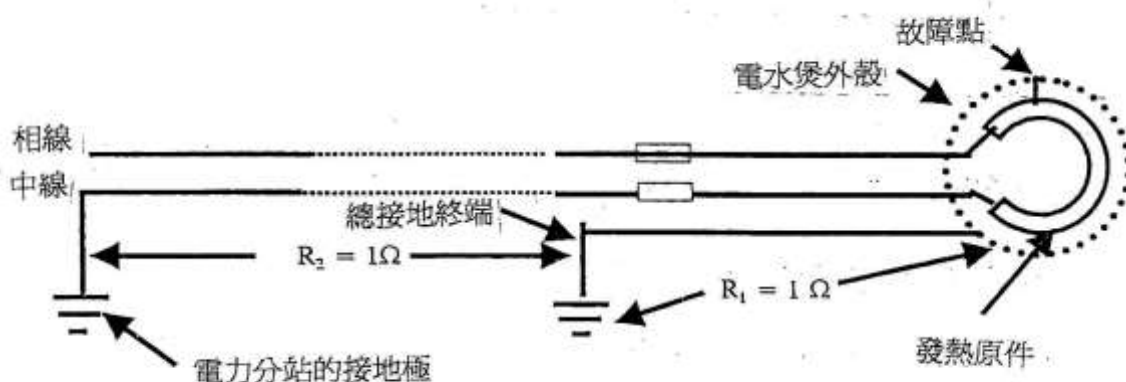


圖 Q6

有一個 2 千瓦(kW)電水煲，電源是 220 伏特(V)。發熱原件上發生接地故障，故障是經由水煲金屬外殼接地，位置離相終端四分之一長度，如圖 Q6 所示。電水煲是由一個 15 安培(A)熔斷器保護，在 47 安培(A) 電流情況下，熔斷器會在 1 秒熔斷。在 33 安培(A) 電流情況下，在 10 秒熔斷。在 28 安培(A) 電流情況下，則在 1 分鐘熔斷。

假設電水煲外殼與樓宇的總接地終端間的電阻(R_1)是 1 歐姆(Ω)。總接地終端至電力分站的接地極間的電阻(R_2)也是 1 歐姆(Ω)。不理會該供電電路上電線的電阻，以及發熱原件與接地故障點間的電阻，

- (i) 試計算出故障電流。
- (ii) 試計算出水煲金屬外殼與電力分站的接地極間的電壓。
- (iii) 試說明該熔斷器或發熱原件會否被燒掉。

- Q7 (a) 試寫出電流波型的總諧波失真率(THD)的定義。
簡單地畫出一個典型的電流波型，而該電流波型只含單數諧波，但不含雙數諧波。試說明這類波型的特點。
- (b) 為提高能源效益的原故，很多樓宇將鎢絲燈照明系統，轉換為附有電子鎮流器的放電燈照明系統。試說明這個轉變對樓宇內電力裝置的正負面影響，並且對負面影響提出補救建議。
- (c) 試為一間課室設計一套照明系統，目標是要使離地 0.9 米(m)的工作面有最小 600 勒克斯(lux)的照明度。有關資料如下：
- 課室大小：5 米（長）× 10 米（闊）× 3.4 米（高）。
 - 黑板位置：在長度為 5 米的牆的正中，黑板高度與牆一樣。
 - 反光率：天花：0.7；牆身：0.5；地板：0.2。
 - 總光損耗因數估計是：0.78。
 - 照明器(型號：SDW236)是安裝在天花的表面。
 - 每一照明器有兩支螢光管，每支管的平均初始流明值是 2500 流明(lumen)。
 - 照明器的光學數據（註）。
- (i) 簡單地畫出你的系統設計，包括你所提議的照明器的方位。無須對眩光指數作詳細計算，但要注意橫向與縱向眩光指數的比較值。
- (ii) 在你設計的系統下，課室地板上的照明度將是多少？
- (iii) 如果除了最近黑板的一個照明器外，其他的照明器都關掉，黑板正中央的照明度將是多少？

註：照明器的數據列載於有關試卷之附頁。

Q8 參考圖 Q8，圖中負載的相導體是連接至分電箱 P，而它的中性導體是連接至分電箱 Q。

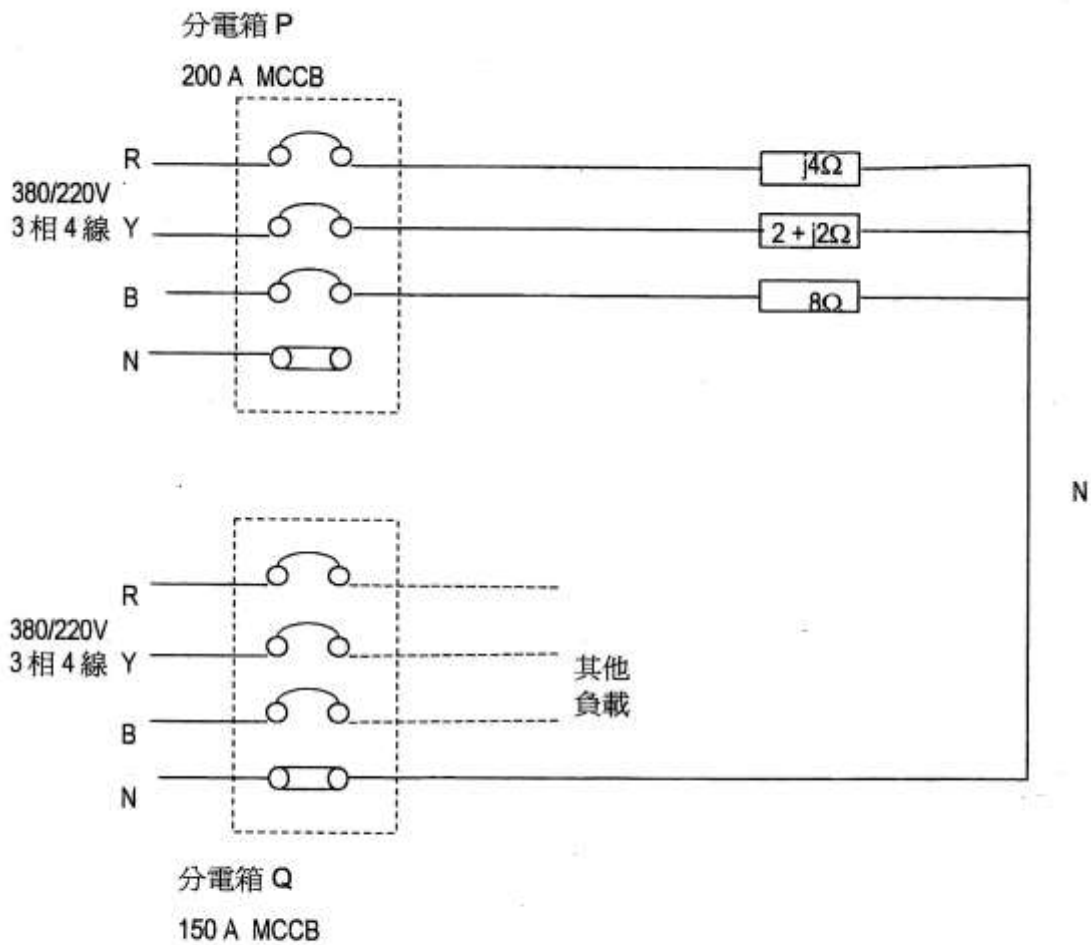


圖 Q8

- 計算在負載裡面的電流。
- 假如 150 安培(A)分電箱(分電箱 Q)的中性連杆被開路，試用【密爾曼定理】或其他方法，來計算出負載的中性導體的電壓。
- 試指出問題所在和這個連接方法的潛在危險。
- 假如兩個分電箱皆有電流式漏電斷路器(RCD)作保護，試陳述將有何事發生？