NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING

TAFE NSW

Family Name .....

Given Name .....

Student Number .....

Centre .....

Signature .....

WITH ANSWER GUIDE

*3 December 2009*

# 6077AC Electrical Systems Safety – Capstone Assessment

***Time allowed – Three hours plus Ten minutes reading time***

***27 Pages in this Question Booklet***

**TOTAL MARKS AVAILABLE =100**

**Aids to be supplied by college:**

- None.

**Aids to be supplied by student:**

- Australian/New Zealand Wiring Rules AS/NZS 3000:2007 (incorporating amendment 1).
- AS/NZS 3008:1.1 Electrical Installations – Selection of Cables, Part 1.1:1998.
- Service and Installation Rules of NSW, October 2007 (incorporating amendment 1).
- Student's own marginal notes, indexing and formal amendments may be included in the above regulation books.
- Pen, pencil, eraser, rule, calculator.

| Section | Possible Marks | Achieved Marks |
|---|---|---|
| A | 20 | |
| B | 30 | |
| C | 35 | |
| D | 15 | |
| Total | 100 | |

**Instructions to student:**

- **Mobile phones are to be turned off and removed from your person.** You cannot access a mobile phone during this examination.
- All questions are to be attempted.
- All questions are to be answered in the space provided in this Question Booklet. Answers to Section A (multiple choice questions) are to be recorded on the Answer Sheet on Page 25 of this Question Booklet.
- You are not to use any other reference books in this examination.
- The whole of this paper is to be handed to the supervisor upon completion.

**Aids permitted where indicated:**

| Standard Dictionaries | Bilingual Dictionaries | Technical Dictionaries | Programmable Calculators | Non-programmable Calculators | Electronic Devices |
|---|---|---|---|---|---|
| No | Yes | No | No | Yes | No |

# SECTION A – (20 Marks)

**Instructions:** Select the best answer for the following statements and place an '**X**' in the appropriate box on the Answer Sheet on Page 25 of this Question Booklet.

**QUESTION 1. (1 Mark)**

The route of an underground cable:

(a) Must be marked at the entry or exit from a structure

(b) Need not be identified if 500 mm deep

(c) Must be marked on a plan stored at the originating switchboard

(d) Must be made known to the customer

**QUESTION 2. (1 Mark)**

The conductor that connects the main earthing terminal, connection or bar to the earth electrode or to the earthing system of the source of supply is known as?

(a) Main neutral conductor

(b) Neutral conductor

(c) Main earth bonding conductor

(d) Main earth conductor

**QUESTION 3. (1 Mark)**

Where is the point of supply in an electrical installation?

(a) Where the service mains cross the property boundary

(b) Where the consumers mains enter the building

(c) The junction of the consumers mains with the conductors of an electricity distribution system; or output terminals of an electricity generating system within the building

(d) The junction of the consumers mains with the conductors of any outgoing circuits including all final sub-circuits and sub-mains

**QUESTION 4. (1 Mark)**

What is the most common method of fault protection?

(a) Automatic disconnection of the supply

(b) Use of class II equipment or equivalent insulation

(c) Electrical separation of the system, in accordance with clause 1.5.5.5 AS/NZS 3000/2007

(d) Limit the fault current that can pass through a body to a value lower than the shock current

# SECTION A – (Cont'd)

**QUESTION 5. (1 Mark)**

What are the limits for touch voltage?

(a) 12 Vac or 32 Vdc

(b) 32 Vac or 50 Vdc

(c) 50 Vac or 120 V ripple-free dc

(d) 50 Vac or 500 V ripple-free dc

**QUESTION 6. (1 Mark)**

When the maximum demand is determined by measurement, the demand shall be determined:

(a) Over any 15 minute period

(b) Over any 15 minute period when the highest demand is recorded

(c) By the highest indication of an ammeter connected to the supply

(d) By the current setting of a fixed setting circuit-breaker, or by the load setting of an adjustable circuit-breaker

**QUESTION 7. (1 Mark)**

A main switch that is used to isolate a portion of an electrical installation supplying the lighting and power circuits shall be marked:

(a) Main switch

(b) Main switch final sub-circuits

(c) Main switch (power and light)

(d) Main switch (domestic portion)

**QUESTION 8. (1 Mark)**

What is the maximum mounting height for a main switch?

(a) 1.2 m

(b) 1.8 m

(c) 2.0 m

(d) 2.5 m

# SECTION A – (Cont'd)

**QUESTION 9. (1 Mark)**

How are isolation devices required to be identified?

(a) They shall be marked to indicate the circuits that they isolate

(b) They shall be legibly and permanently identified

(c) They shall be labelled to indicate the type of equipment they isolate

(d) They shall be marked legibly and permanently indicating the circuits that they isolate

**QUESTION 10. (1 Mark)**

How must a socket outlet be marked if it is used to supply a fixed hotplate unit, which is installed in a cupboard in a domestic installation and not protected by an RCD?

(a) Hotplates only 'Not RCD Protected'

(b) Range

(c) Hotplates

(d) Does not require marking

**QUESTION 11. (1 Mark)**

When cables are installed in a ceiling space of a new domestic residence, what would be the installation conditions for selecting the cables if the cables are lying flat on the ceiling material?

(a) On a surface

(b) On a surface partially surrounded by thermal insulation

(c) On a surface fully surrounded by thermal insulation

(d) Enclosed

**QUESTION 12. (1 Mark)**

The value of current used for the calculation of voltage drop on a circuit need not exceed:

(a) The total connected load supplied through the circuit

(b) The maximum demand of the circuit

(c) The current rating of the circuit protective device

(d) All of the above

# SECTION A – (Cont'd)

**QUESTION 13. (1 Mark)**

What type of insulation must be used to replace removed or damaged insulation when joining cables?

(a) Reinforced insulation

(b) PVC tape

(c) Insulation which is not inferior to that which was removed

(d) Encapsulated in resin

**QUESTION 14. (1 Mark)**

How much conductor insulation may be removed when making a termination at a socket outlet mounted on a hollow wall?

(a) 100 mm

(b) Only as much as necessary

(c) 50 mm

(d) 30 mm

**QUESTION 15. (1 Mark)**

Structural steelwork associated with a particular electrical installation is required to connect to the earth. What are the requirements for the conductor that connect the steelwork to the earth bar?

(a) 4 $mm^2$ bonding conductor not exceeding 0.5 ohms

(b) 2.5 $mm^2$ protective earth conductor not exceeding 0.5 ohms

(c) Appropriate size protective earth conductor not exceeding 0.5 ohms

(d) Appropriate size bonding conductor not exceeding 0.5 ohms

**QUESTION 16. (1 Mark)**

The minimum depth of cover required over a category B external underground wiring system is:

(a) Directly below 75 mm concrete

(b) 300 mm below 75 mm concrete

(c) 500 mm below 75 mm concrete

(d) 50 mm below 75 mm concrete

# SECTION A – (Cont'd)

**QUESTION 17. (1 Mark)**

What minimum clearance is required between a clothes line and a catenary cable used to supply a backyard garage?

(a) 1.2 m

(b) 2.0 m

(c) 2.7 m

(d) 3.0 m

**QUESTION 18. (1 Mark)**

What is the maximum length of unprotected interconnecting cables for an electricity converter?

(a) 3 m

(b) 10 m

(c) 15 m

(d) 30 m

**QUESTION 19. (1 Mark)**

Where double insulation is maintained between the point of supply and the load terminals of the protective devices for the sub-mains and final sub-circuits, the size of the main earth may be determined by:

(a) The largest active conductor of the largest outgoing sub-main or final sub-circuit

(b) The consumers mains

(c) The maximum permissible fault current

(d) 4 $mm^2$

**QUESTION 20. (1 Mark)**

An insulation resistance tester should operate at what voltage for 230 V wiring?

(a) 500 V

(b) 450 – 550 V

(c) 450 – 600 V

(d) 460 V

# (END OF SECTION A)

# SECTION B – (30 Marks)

**Instructions:** Blank spaces in the following statements represent omissions. Write the appropriate word, words or information in the space provided.

- Use AS/NZS 3000:2007 to best answer each question.
- **Write the specific reference from AS/NZS 3000:2007 clause or table numbers when answering the questions.**

**QUESTION 1. (2 Marks)**

A timber batten is required to provide mechanical protection for an unarmoured sheathed cable in a roof space passes where it passes over a joist in an accessible location. What size timber batten should be placed beside the cable if the cable height is 20 mm?

.....

.....

(AS/NZS 3000:2007 Reference: .....)

**QUESTION 2. (2 Marks)**

When determining the maximum demand of a final sub-circuit in a domestic installation, what is the demand of a hotplate and an oven having a combined load of 12.6 kW?

.....

.....

(AS/NZS 3000:2007 Reference: .....)

**QUESTION 3. (2 Marks)**

When selecting an isolating switch for a motor and the motor manufacturer has not provided any specific information as to the starting current, the locked rotor or stall current shall be taken as:

.....

.....

(AS/NZS 3000:2007 Reference: .....)

**QUESTION 4. (2 Marks)**

What distance is required between a combustible structural member and a halogen lamp?

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.....

(AS/NZS 3000:2007 Reference: .....)

# SECTION B – (Cont'd)

**QUESTION 5. (2 Marks)**

Where the open circuit position is not readily distinguishable, how must circuit-breakers be orientated when mounted in the same row?

.....

.....

(AS/NZS 3000:2007 Reference: .....)

**QUESTION 6. (2 Marks)**

Is additional circuit protection required for exhaust fans and ceiling sweep fans located in residential installations?

.....

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(AS/NZS 3000:2007 Reference: .....)

**QUESTION 7. (2 Marks)**

The operating characteristics of a protective device protecting a conductor against overload shall satisfy what two conditions?

.....

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(AS/NZS 3000:2007 Reference: .....)

**QUESTION 8. (2 Marks)**

Which standard should be used for the guidance on the selection, installation and control of a photo-voltaic array?

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.....

(AS/NZS 3000:2007 Reference: .....)

# SECTION B – (Cont'd)

**QUESTION 9. (2 Marks)**

When performing an insulation resistance test on a circuit containing surge diverters, what voltage may be used if the device is likely to be damaged? What is the minimum acceptable reading?

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(AS/NZS 3000:2007 Reference: .....)

**QUESTION 10. (2 Marks)**

When using an ohmmeter to measure fault loop impedance and supply is not available, which conductors should be connected together and where?

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(AS/NZS 3000:2007 Reference: .....)

**QUESTION 11. (2 Marks)**

In wet conditions, how long could a touch voltage of 70 volts be sustained by a person?

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(AS/NZS 3000:2007 Reference: .....)

**QUESTION 12. (2 Marks)**

What is the maximum conductor length, connecting surge protective devices?

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(AS/NZS 3000:2007 Reference: .....)

# SECTION B – (Cont'd)

**QUESTION 13. (2 Marks)**

What is the minimum size of bare copper cable used as earth electrode?

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(AS/NZS 3000:2007 Reference: .....)

**QUESTION 14. (2 Marks)**

What is the maximum rating of a three-phase induction motor that is not required to have over-temperature protection?

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(AS/NZS 3000:2007 Reference: .....)

**QUESTION 15. (2 Marks)**

Where conductors or cables are required to pass through a conduit, what are the requirements for the ends of the conduit?

.....

.....

(AS/NZS 3000:2007 Reference: .....)

# (END OF SECTION B)

## SECTION C – (35 Marks)

**Instructions:** This section involves calculations. Show all necessary working in the space provided. Marks will be awarded accordingly. **Answers are to be highlighted or underlined.** Answer the following questions clearly in the space provided in this Question Booklet.

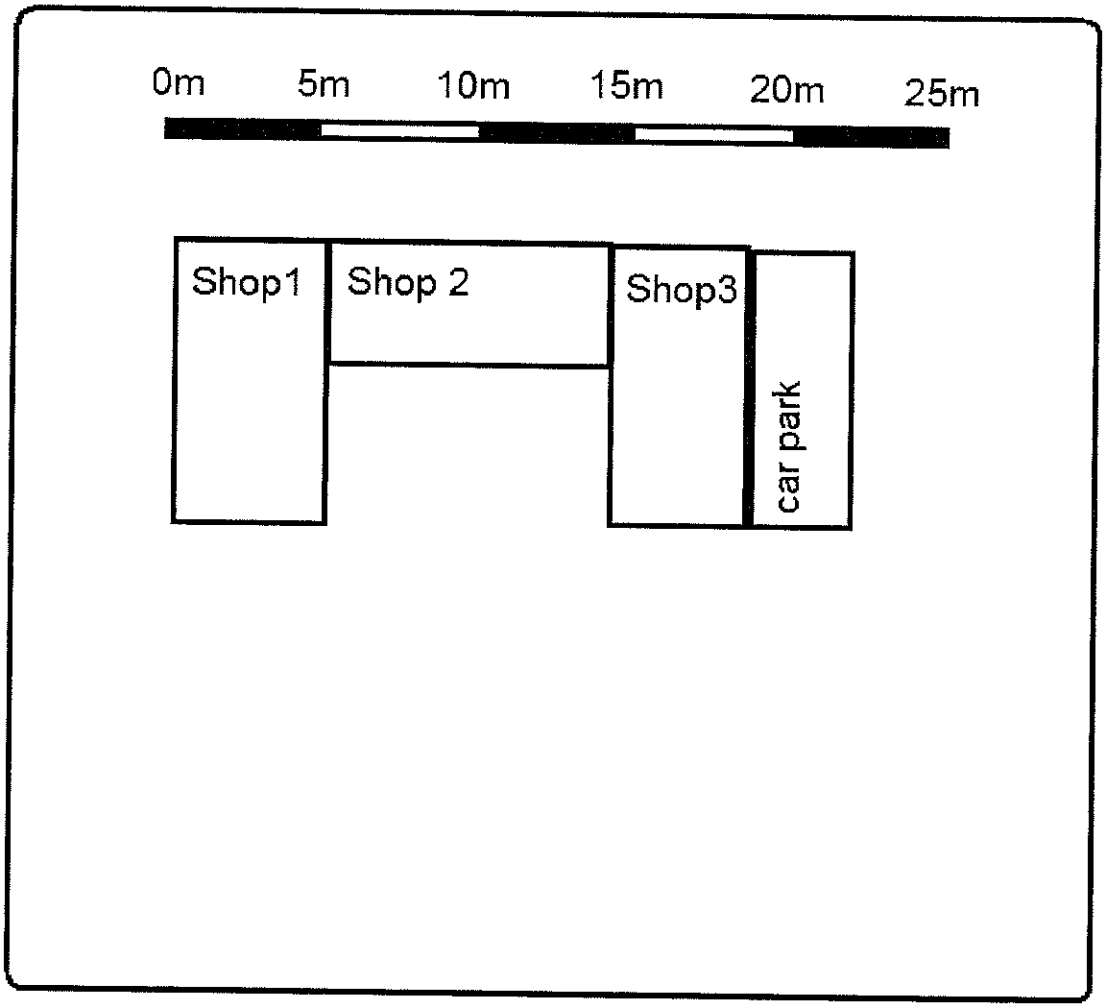


**Figure 1**

Marks

## SECTION C – (Cont'd)

**QUESTION 1. (4 Marks)**

The small shopping village of Figure 1 is supplied by overhead aerial service mains to a point of attachment at the rear of Shop 1. The main switchboard is located directly below the point of attachment with the consumers mains being three-phase, SDI V75 cables, having a route length of 6 metres and run through a cavity wall. (Shops 1 and 3 do not have air conditioning.)

**2** (a) Based on floor area, calculate the **maximum demand** and minimum size of the unprotected **consumers mains**. Each shop has a floor area of 50 $m^2$ and the car park is 35 $m^2$.

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**1** (b) Calculate the size of the main earth.

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**1** (c) What are the requirements for the location and marking of the main earth?

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## SECTION C – (Cont'd)

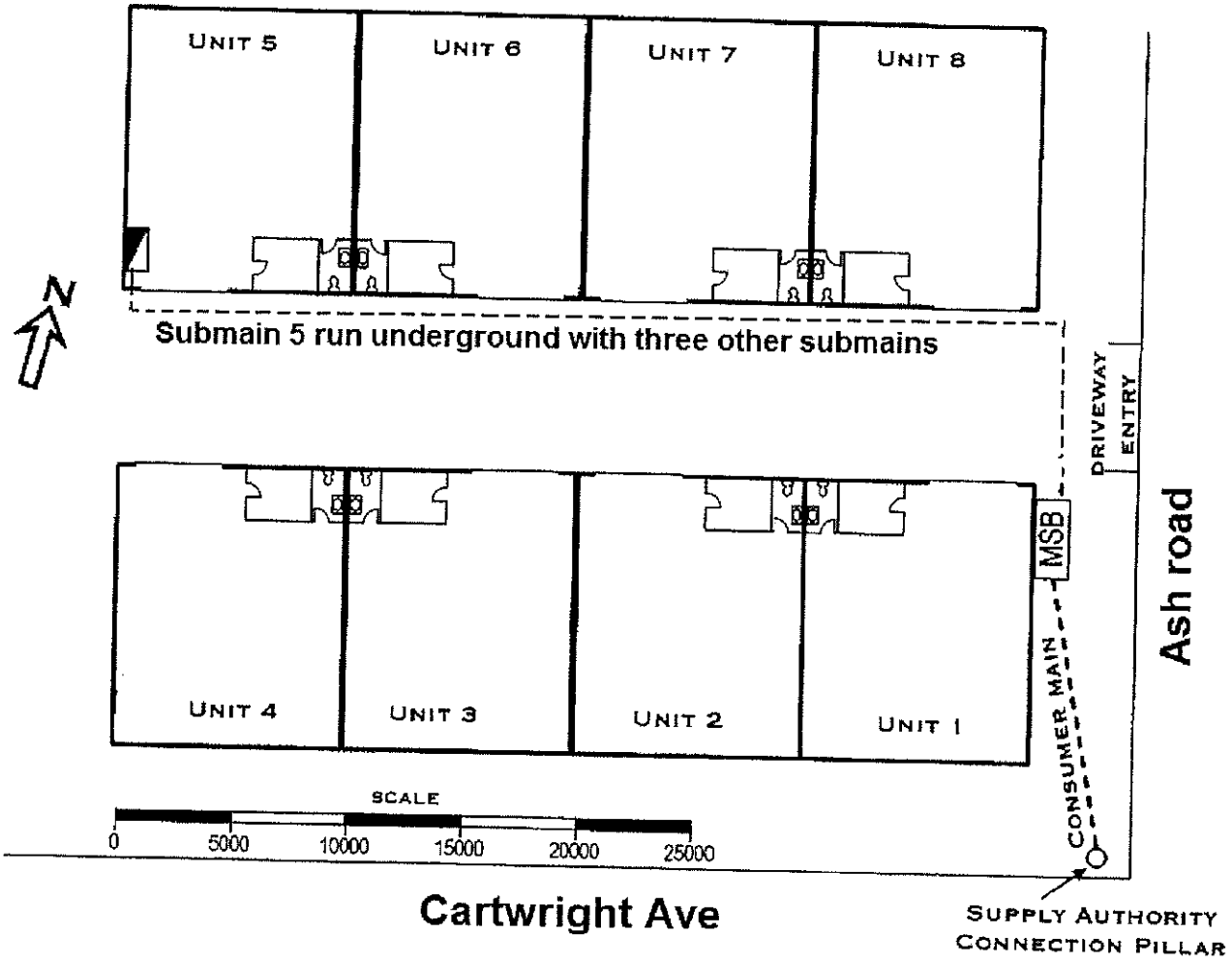


Figure 2

## SECTION C – (Cont'd)

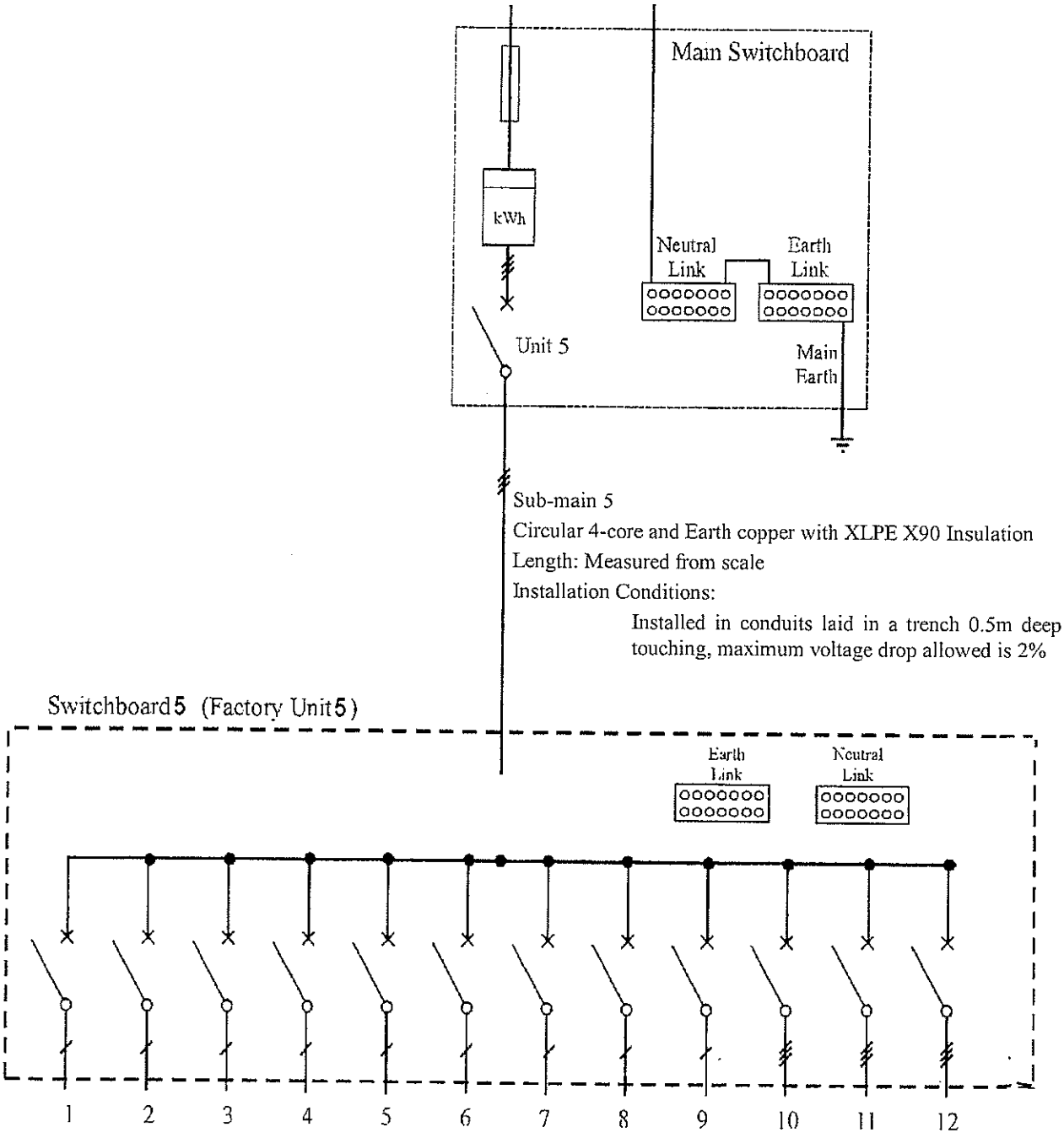


**Figure 3**

**Marks**

## SECTION C – (Cont'd)

**Table 1**

| Circuit | Description | Quantity | Fitting Rating |
|---|---|---|---|
| 1 | Fluorescent lighting office | 12 | 0.7 A |
| 2 | Fluorescent lighting factory | 14 | 0.7 A |
| 3 | Air extraction fan | 1 | 1.5 hp 8 A |
| 4 | Single-phase socket outlet – office | 12 double | 10 A |
| 5 | Single-phase socket outlet – factory | 10 double | 10 A |
| 6 | Single-phase socket outlet – factory | 3 | 15 A |
| 7 | Single-phase socket outlet – factory | 1 | 25 A |
| 8 | Three-phase socket outlet – factory | 1 | 40 A |
| 9 | Drill press | 1 | 12.5 A |
| 10 | Compressor | 1 | 20 A |
| 11 | 6 kW Air conditioner | 1 | 6 A / phase |
| 12 | 6 kW Instantaneous HWS | 1 | 6 kW |

**QUESTION 2. (4 Marks)**

**2** (a) If sub-main 5 supplying factory Unit 5 in Figure 2 has a maximum demand of 53 A, determine the minimum conductor size based on current carrying capacity when installed as shown in Figure 2 and Figure 3.

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.....

**2** (b) If the sub-main to factory Unit 1 in Figure 2 was installed close to the roof where the ambient air temperature could reach 55°C, what de-rating factor would apply to the cable?

.....

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# SECTION C – (Cont'd)

**QUESTION 3. (3 Marks)**

The three-phase, 230/400 V consumer main to the block of factory units consists of SDI cables having circular copper conductors. The active conductors are 150 $mm^2$. The supply authority nominates the fault level at the point of supply 25 kA. The soil resistivity is very low. The cable route length may be measured off the plan to the edge of the main switchboard. Calculate the theoretical fault current active to earth at the main switchboard.

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**QUESTION 4. (6 Marks)**

Calculate the maximum demand of the three-phase sub-main to Unit 5 shown in Figure 3 using the information provided in Table 1.

| Load Group | Load Description | Qty | Calculation | Demand A Phase | Demand B Phase | Demand C Phase |
|---|---|---|---|---|---|---|
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The maximum demand of Unit 5 is ..... A per phase.

Marks

## SECTION C – (Cont'd)

**QUESTION 5. (2 Marks)**

If the maximum demand of the sub-main to Unit 5 in Figure 2 was 110 A, what would be the minimum size of the active, neutral and earth conductors, based on current carrying capacity, for a V90 multi-core cable having copper conductors, installed in an underground duct together with three other sub-mains, when protected by a 120 A type 'D' circuit-breaker?

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Size based on current carrying capacity .....

**QUESTION 6. (3 Marks)**

If the maximum demand of Unit 5 in Figure 2 was 85 A, and the sub-main supplying Unit 5 is X90 multi-core cables having 50 $mm^2$ circular copper conductors, would the voltage drop be within the specified limit of 2.0% if the length of the sub-main is 50 metres?

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2 Actual voltage drop .....

1 Within 2.0% limit .....

**QUESTION 7. (3 Marks)**

If the sub-main cable to Unit 5 in Figure 2 was protected by an 85 A type 'D' circuit-breaker, calculate the tripping time for circuit-breaker if the source impedance at the MSB is 0.015 ohms.

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2 Tripping time .....

1 Is the time within the maximum allowed tripping time for a sub-main? .....

# SECTION C – (Cont'd)

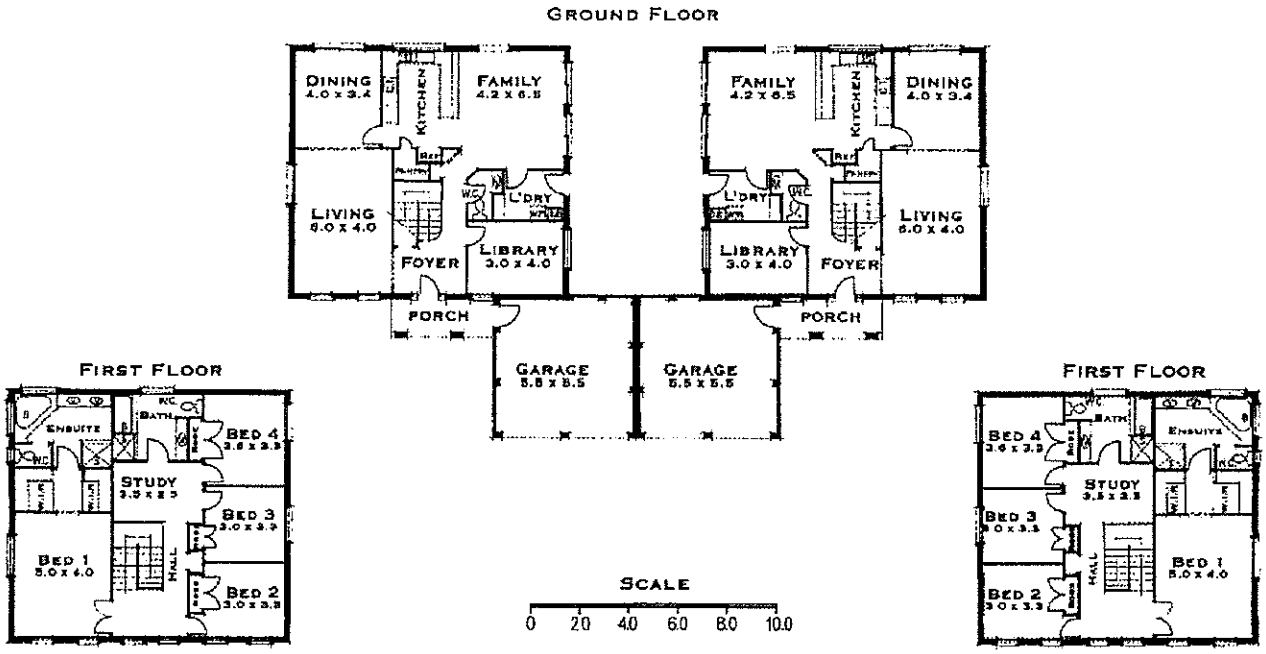


**Figure 4**

**QUESTION 8. (5 Marks)**

Calculate the maximum demand for one of the above duplex dwellings with the following load.

**Table 2**

| Circuit | Description | Quantity | Load |
|---|---|---|---|
| 1 | Low voltage down lights | 20 | 50 W |
| 2 | Low voltage down lights | 20 | 50 W |
| 3 | Compact fluorescents | 10 | 15 W |
| 4 | Single-phase socket outlets | 16 double | 10 A |
| 5 | Single-phase socket outlets | 20 double | 10 A |
| 6 | Single-phase socket outlets | 1 | 15 A |
| 7 | Single-phase cook top (20 A SO) | 1 | 7.8 kW |
| 8 | Single-phase oven/grill (20 A SO) | 1 | 5.6 kW |
| 9 | Security system and smoke alarm | 1 | 0.5 A |
| 10 | Single-phase air conditioner | 1 | 12.6 A |
| 11 | Solar booster element (controlled load) | 1 | 3.6 kW |

# SECTION C – (Cont'd)

**QUESTION 8. (Cont'd)**

| Load Group | Load Description | Qty | Calculation | Demand |
|---|---|---|---|---|
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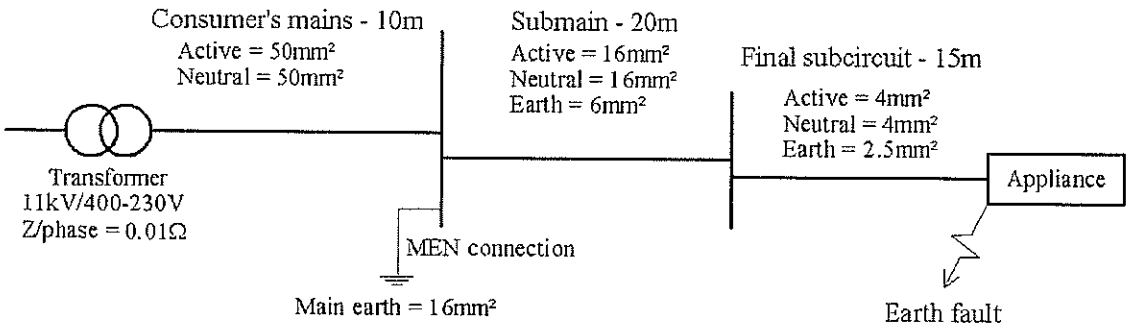
Maximum demand .....

# SECTION C – (Cont'd)

**QUESTION 9. (5 Marks)**

The diagram below shows a single line diagram representing a supply transformer, consumer mains XLPE X90 to a main switchboard, sub-main XLPE X90 to a distribution board, and a final sub-circuit V75 to an appliance. An earth fault of zero impedance occurs at the appliance. Calculate the total fault loop impedance.

*(Note: Assume the fault current returns to the supply via the consumers main's neutral.)*

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## (END OF SECTION C)

# SECTION D – (15 Marks)

**Instructions:** The questions in this section require some simple drawing. Ensure that the drawing is neat and legible. The use of pencil on the drawing is acceptable in this section only.

Figure 5 shows the time-current characteristic curves for type 'C' and type 'D' thermal-magnetic circuit-breakers of a particular manufacturer. Use this information to answer Question 1 and Question 2 of this section.

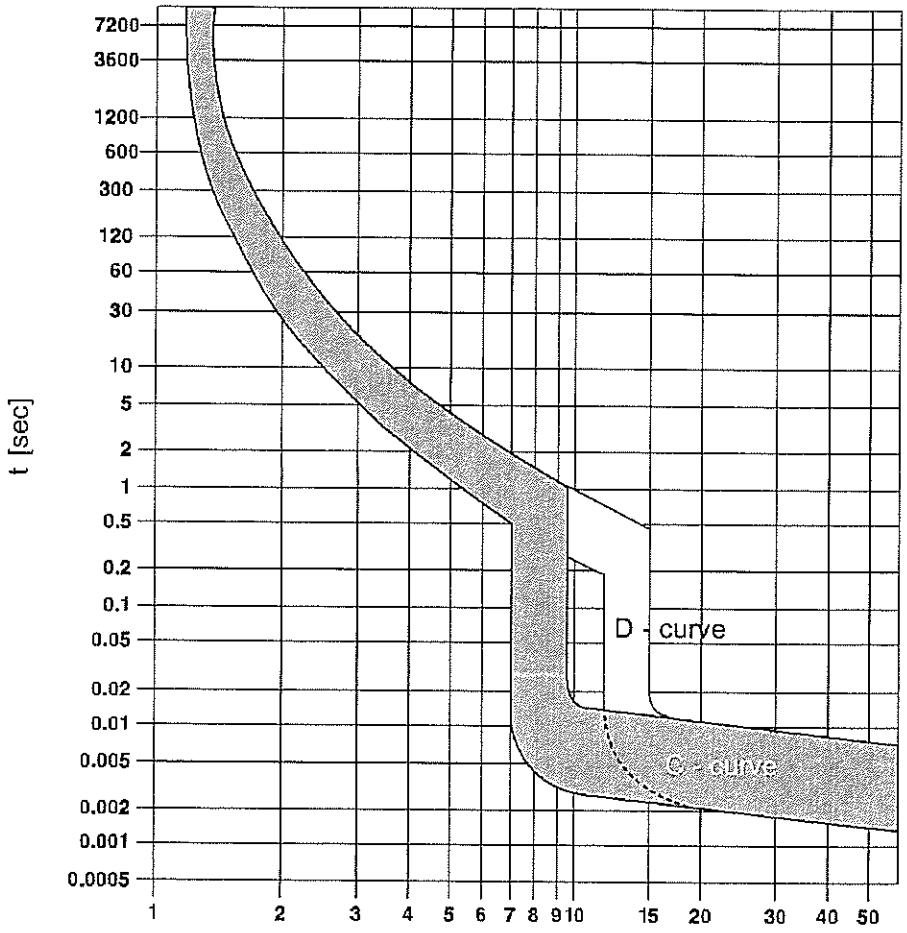


**Figure 5**

# SECTION D – (Cont'd)

**QUESTION 1. (3 Marks)**

A three-phase motor with an earthed metallic frame is to be permanently installed in a fixed position and connected via an isolation switch. The final sub-circuit to the motor is to be protected by a 40 Amp type 'D' thermal-magnetic circuit-breaker. Using the characteristic curve shown in Figure 5, determine the value of current required to **ensure** the protective device operates within the specified time required by AS3000, in order to protect against indirect contact.

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**QUESTION 2. (2 Marks)**

A circuit is to be protected by a 50 Amp type 'C' circuit-breaker. Using the circuit-breaker characteristic curve of Figure 5, determine the approximate minimum and maximum operating times for a fault current of 200 Amps.

Minimum ..... seconds

Maximum ..... seconds

**QUESTION 3. (5 Marks)**

The diagram on Page 23 represents a portion of a single domestic electrical installation. For simplification, only a small selection of equipment has been shown.

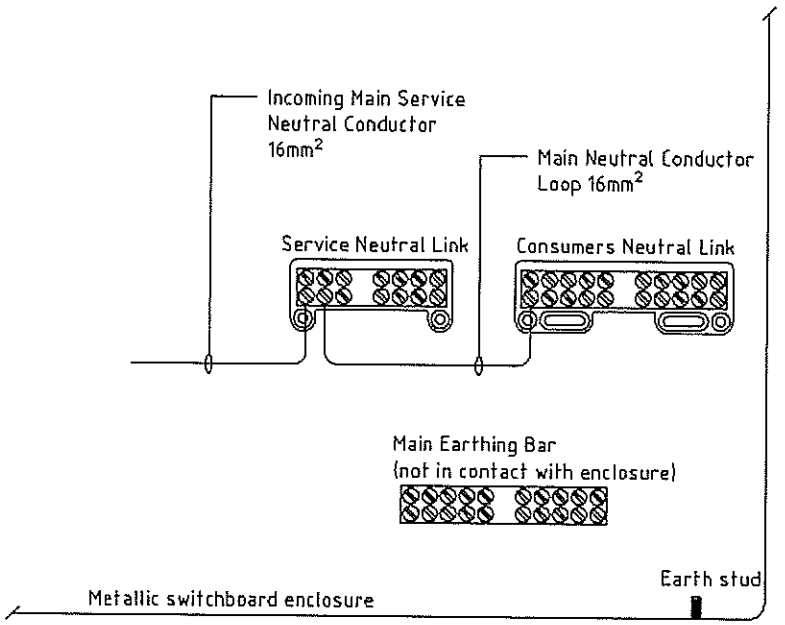
The unprotected consumer mains entering the main switchboard consist of 16 $mm^2$ active and neutral conductors. The consumer mains are single insulated within the metallic enclosure.

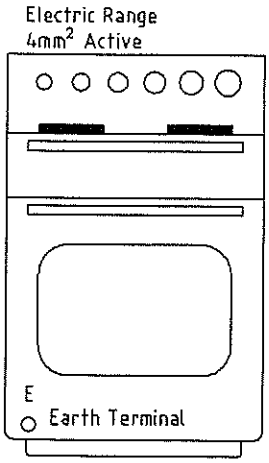
On the diagram (Page 23), neatly draw in all necessary earthing and equipotential bonding conductors required to complete an MEN system of earthing.

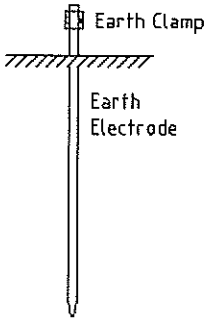
The incoming water service is electrically continuous between the building interior and the ground.

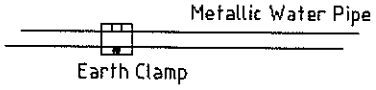
Based on the given information, determine the minimum size of all earthing conductors, which is to be shown alongside each conductor (active and neutral conductors need not be shown).

# SECTION D – (Cont'd)



# SECTION D – (Cont'd)

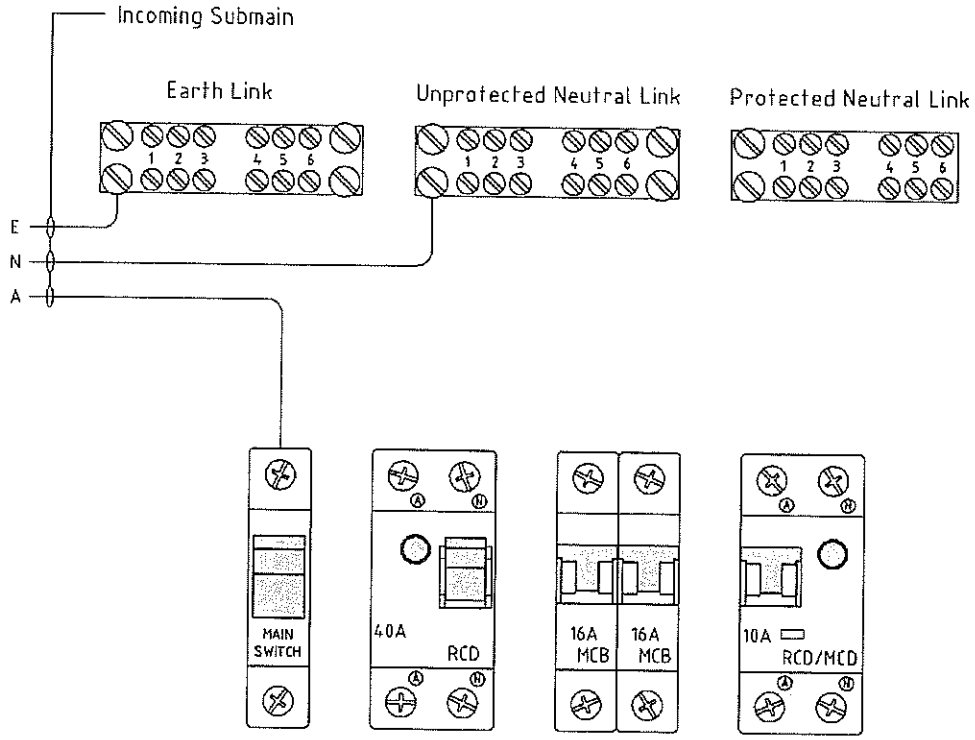
**QUESTION 4. (5 Marks)**

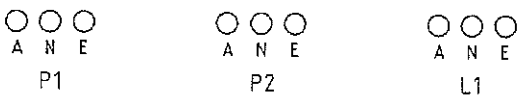
The diagram below represents selected items contained within a domestic electrical distribution board.

Neatly draw in all **active**, **neutral** and **earth** conductors necessary for the safe and proper operation of the circuits.

Power circuits P1 and P2 will be individually protected by their own 16 A MCB. Both circuits (P1 and P2) will also have additional protection by a common 40 A two-pole RCD.

Lighting circuit L1 is to be protected by a 10 A combination RCD/MCB.




# (END OF SECTION D)

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING

TAFE NSW

Family Name .....

Given Name .....

Student Number .....

Centre .....

Signature .....

# ANSWER SHEET – SECTION A (Multiple Choice Questions)

## *3 December 2009*

## 6077AC Electrical Systems Safety – Capstone Assessment

**Instructions:**

- Enter your personal details in the top right hand corner of this sheet.
- Place an '**X**' in the box of your choice. If you make a mistake, circle your answer (X) and choose again.
- For your convenience you can remove this page while you answer Section A. **Remember to re-attach it to this Question Booklet when you hand it in.**

| Question | (a) | (b) | (c) | (d) | | Question | (a) | (b) | (c) | (d) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | 11 | | | | |
| 2 | | | | | | 12 | | | | |
| 3 | | | | | | 13 | | | | |
| 4 | | | | | | 14 | | | | |
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| 7 | | | | | | 17 | | | | |
| 8 | | | | | | 18 | | | | |
| 9 | | | | | | 19 | | | | |
| 10 | | | | | | 20 | | | | |
| **Totals** | | | | | | **Totals** | | | | |

**Total Marks Section A:** ..... **/20**

# END OF EXAMINATION

# MARKING GUIDE

**Module/Unit No:** 6077AC

**Module/Unit Name:** Electrical Systems Safety – Capstone Assessment

**Exam Date:** 3/12/2009

**Number of Pages:** 25 (including this page)

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING

TAFE NSW

Family Name ()

Other name.....

Centre .....

Signature .....

# MARKING GUIDE

*3 December 2009*

## 6077AC Electrical Systems Safety Capstone

*Time allowed – 3 hours plus Ten minutes reading time*

*25 Pages in this Question Booklet*

***All* Questions to be attempted**

**TOTAL MARKS AVAILABLE = 100**

| Section | Possible mark | Actual mark |
|---|---|---|
| A | 20 | |
| B | ~~30~~ 28 | |
| C | 35 | |
| D | 15 | |
| Total | 100 | |

**Aids to be supplied by college**

- None

**Aids to be supplied by student**

- Australian/New Zealand Wiring rules AS/NZS 3000:2007 incorporating Amendment 1
- AS/NZS 3008.1.1 Electrical Installations – Selection of Cables, Part 1.1: 1998
- Service and Installation Rules of NSW, October 2007 (incorporating Amendment 1)
- Students own marginal notes, indexing and formal amendments may be included in the above regulation books.
- Pen, pencil, eraser, rule, calculator

**Instructions to Student**

- **Mobile phones are to be turned off and removed from your person.** You cannot access a mobile phone during this test.
- All questions to be answered in the space provided on this **examination paper.** Answers to Section A – multi-choice questions, are to be answered on the sheet attached to this examination paper.
- You are not to use any other reference book in this examination.
- The whole of this paper is to be handed to the Supervisor upon completion.

**Aids permitted where indicated:**

| Standard Dictionaries | Bilingual Dictionaries | Technical Dictionaries | Programmable Calculators | Non-programmable Calculators |
|---|---|---|---|---|
| No | No | No | No | Yes |

28

## SECTION B – (30 Marks)

**INSTRUCTIONS: Blank spaces in the following statements represent omissions. Write the appropriate word, words or information in the numbered spaces provided.**

- **Use AS/NZS 3000:2007 to best answer each question.**
- **Write the specific reference from AS/NZS 3000:2007 when answering the question required.**

**QUESTION 1. (2 Marks)**

A timber batten is required to provide mechanical protection for an unarmoured sheathed cable in a roof space passes where it passes over a joist in an accessible location. What size timber batten should be placed beside the cable if the cable height is 20mm?

_____ ≥ 40mm_____

_____

___

(AS/NZS 3000:2007 Reference: Fig H1or App. H5.1(b)))

**QUESTION 2. (2 Marks)**

When determining the maximum demand of a final sub-circuit in a domestic installation, what is the demand of a hotplate and oven having a combined load of 12.6kW

_____32A_____

_____

(AS/NZS 3000:2007 Reference: Table C4_ )

**QUESTION 3. (2 Marks)**

When selecting an isolating switch for a motor and the motor manufacturer has not provided any specific information as to the starting current, the locked rotor or stall current shall be taken as-

___8 times full load current for ac motors_____

___4 times full load current for dc motors_____

(AS/NZS 3000:2007 Reference: _4.13.1.2(i)(ii)__ )

**QUESTION 4. (2 Marks)**

What distance is required between a combustible structural member and a halogen lamp?

_____200mm_____

_____

(AS/NZS 3000:2007 Reference: _Figure 4.7_ )

**QUESTION 5.** **(2 Marks)**

Where the open circuit position is not readily distinguishable, how must circuit-breakers be orientated when mounted in the same row?

_____orientated in one general direction

_____

(AS/NZS 3000:2007 Reference: Clause number __2.9.3.4_ )

**QUESTION 6.** **(2 Marks)**

Is additional circuit protection required for exhaust fans and ceiling sweep fans located in residential installations?

_____Yes RCD protection required (AS/NZS 3000:2007 Reference: Clause number 2.6.3.1 (b) note. With Amendment 1)

OR

___No (AS/NZS 3000:2007 Reference: Clause number ___2.6.3.1(b) note. Without Amendment 1)

**QUESTION 7.** **(2 Marks)**

The operating characteristics of a protective device protecting a conductor against overload shall satisfy what two conditions?

_____$I_B \leq I_N \leq I_Z$___and___$I_2 \leq 1.45 \times I_Z$

_____

_____

(AS/NZS 3000:2007 Reference: Clause number __2.5.3.1__ OR App. B3.2.1)

**QUESTION 8.** **(2 Marks)**

Which standard should be used for the guidance on the selection, installation and control of a photo-voltaic array?

_____AS/NZS5033_____

(AS/NZS 3000:2007 Reference: Clause number 7.3.2(d) OR App A)

**QUESTION 9.** **(2 Marks)**

When performing a insulation resistance test on a circuit containing surge diverters, what voltage may be used if the device is likely to be damaged when using the 500V setting? What is the minimum acceptable reading?

_____250V and not less than 1 meg ohm_____

(AS/NZS 3000:2007 Reference: Clause number ___8.3.6 Ex 1(ii))

**QUESTION 10.** **(2 Marks)**

When using an ohmmeter to measure fault loop impedance and supply is not available, which conductors should be connected together and where?

_____active and earth at the origin of the particular circuit____

(AS/NZS 3000:2007 Reference: Clause number __8.3.9.3(a)(i)_____ )

**QUESTION 11.** **(2 Marks)**

In wet conditions how long could a touch voltage of 70Volts be sustained by a person?

_____300 msec to 340 msec_____

(AS/NZS 3000:2007 Reference: Clause number __figure B4__ )

This question → OUT!

**QUESTION 12.** **(2 Marks)**

What is the maximum length conductor connecting surge protective devices?

___less than one meter____phase and neutral_____

(AS/NZS 3000:2007 Reference: Clause number _F1.2.5_and_F1.2.2(b)_ )

**QUESTION 13.** **(2 Marks)**

What is the minimum size of bare copper cable used as earth electrode?

25mm$^2$ (AS/NZS 3000:2007 Reference: Clause number __T5.2 Based on Amendment 1)

OR 35 mm$^2$ (AS/NZS 3000:2007 Reference: Clause number __T5.2 Without Amendment 1)

**QUESTION 14.** **(2 Marks)**

What is the maximum rating of a three phase induction motor that is not required to have over-temperature protection?

_____2250 W_____

(AS/NZS 3000:2007 Reference: Clause number ___4.13.3.1(b)__ )

**QUESTION 15.** **(2 Marks)**

Where conductors or cables are required to pass through a conduit what are the requirements for the ends of the conduit?

____ have sharp edges removed_____

(AS/NZS 3000:2007 Reference: Clause number _3.10.3.5(a) and (b)__ )

Alternate Answer

Installed in a manner that will prevent water from entering

3.10.2.3 a)

## SECTION C – (35 Marks)

**INSTRUCTIONS: This section involves calculations. Show all necessary working in the space provided, marks will be awarded accordingly. Answers are to be highlighted or underlined.**

**INSTRUCTIONS: Answer the following questions in the spaces provided.**

**INSTRUCTIONS: Clearly write your answers in the space provided.**

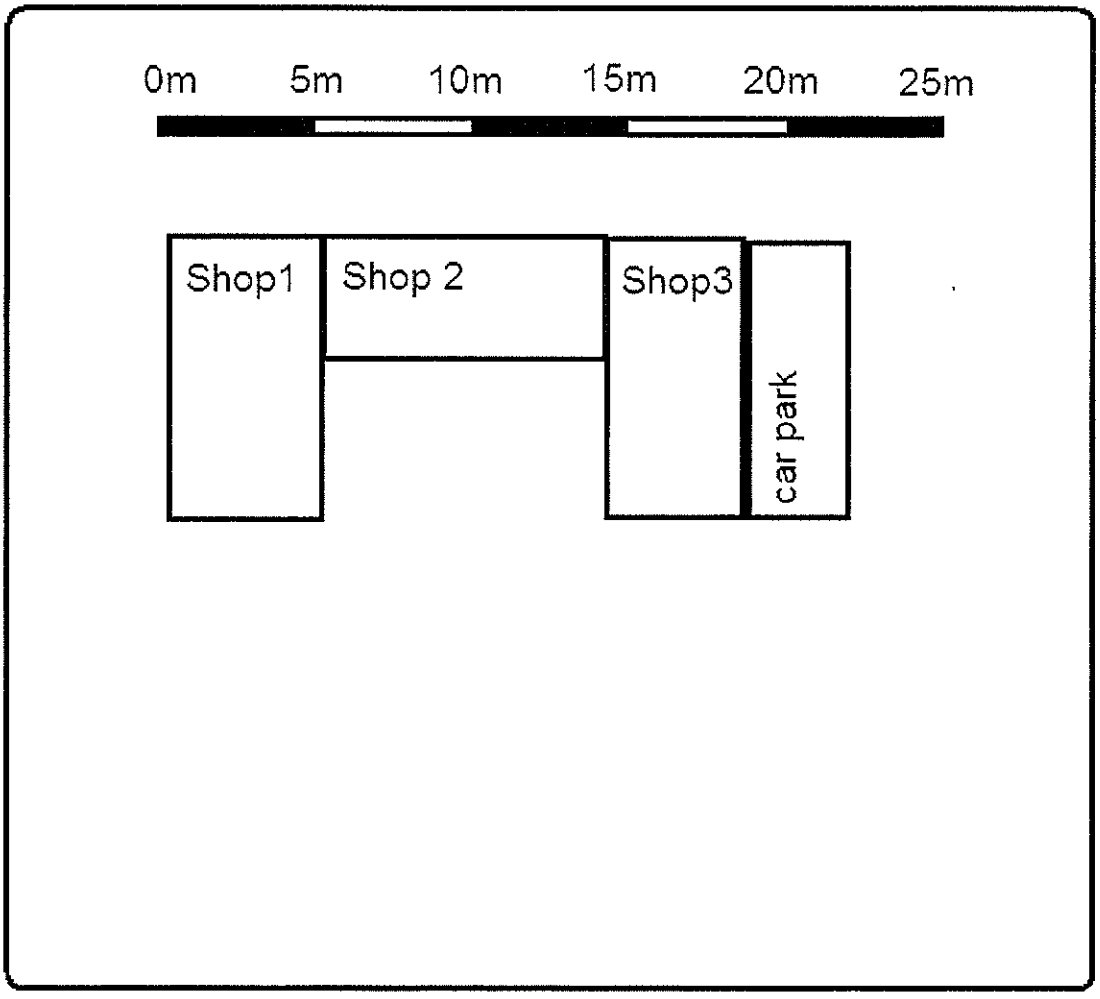



**Figure 1**

**QUESTION 1.** **(4 Marks)**

The small shopping village of **Error! Reference source not found.** is supplied by overhead aerial service mains to a point of attachment at the rear of shop 1. The main switchboard is located directly below the point of attachment with the consumers mains being 3-phase, SDI V75 cables, having a route length of 6 metres and run through a cavity wall. (Shops 1 and 3 do not have air conditioning) (2 marks)

(a) Based on floor area, calculate the **maximum demand** and minimum size of the unprotected **consumers mains**. Each shop has a floor area of $50m^2$ and the car park is $35m^2$.(2marks)

Reference : Table C3

Each shop $50m^2$

Shop 1,3 VA = 2 x 50 x 70 = 7000VA (light & power)

Shop 2 VA = 50 x 100 = 5000VA (light, power & air cond)

Car Park = 35 x5 = 175VA (open air carpark)

Total VA = 12,175VA

Per phase = 4058VA $\left(\frac{12175}{3}\right)$

Maximum demand = 4058/230 = 17.6A

Minimum size $16mm^2$ NSW Service Rules

(b) Calculate the size of the main earth (1mark)

T5.1 $6mm^2$

(c) What are the requirements for the location and marking of the main earth? (1marks)

Accessible, protected from mechanical damage, protected against corrosion and labelled, "WARNING: MAIN ELECTRICAL EARTHING CONDUCTOR-DO NOT DISCONNECT"

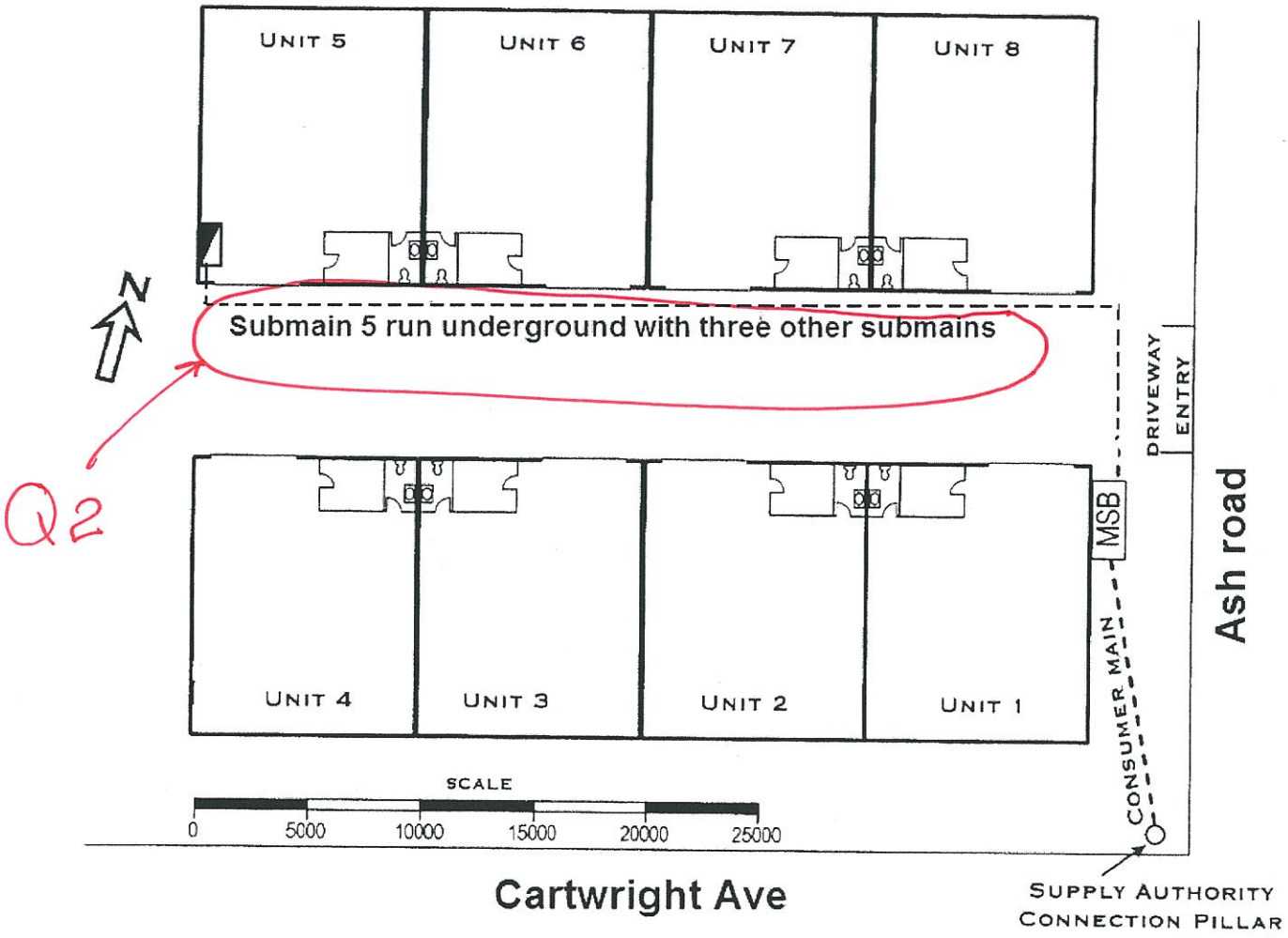

UNIT 5
UNIT 6
UNIT 7
UNIT 8
N
Submain 5 run underground with three other submains
Q2
DRIVEWAY ENTRY
MSB
CONSUMER MAIN
Ash road
UNIT 4
UNIT 3
UNIT 2
UNIT 1
SCALE
0
5000
10000
15000
20000
25000
Cartwright Ave
SUPPLY AUTHORITY CONNECTION PILLAR

**Figure 2**

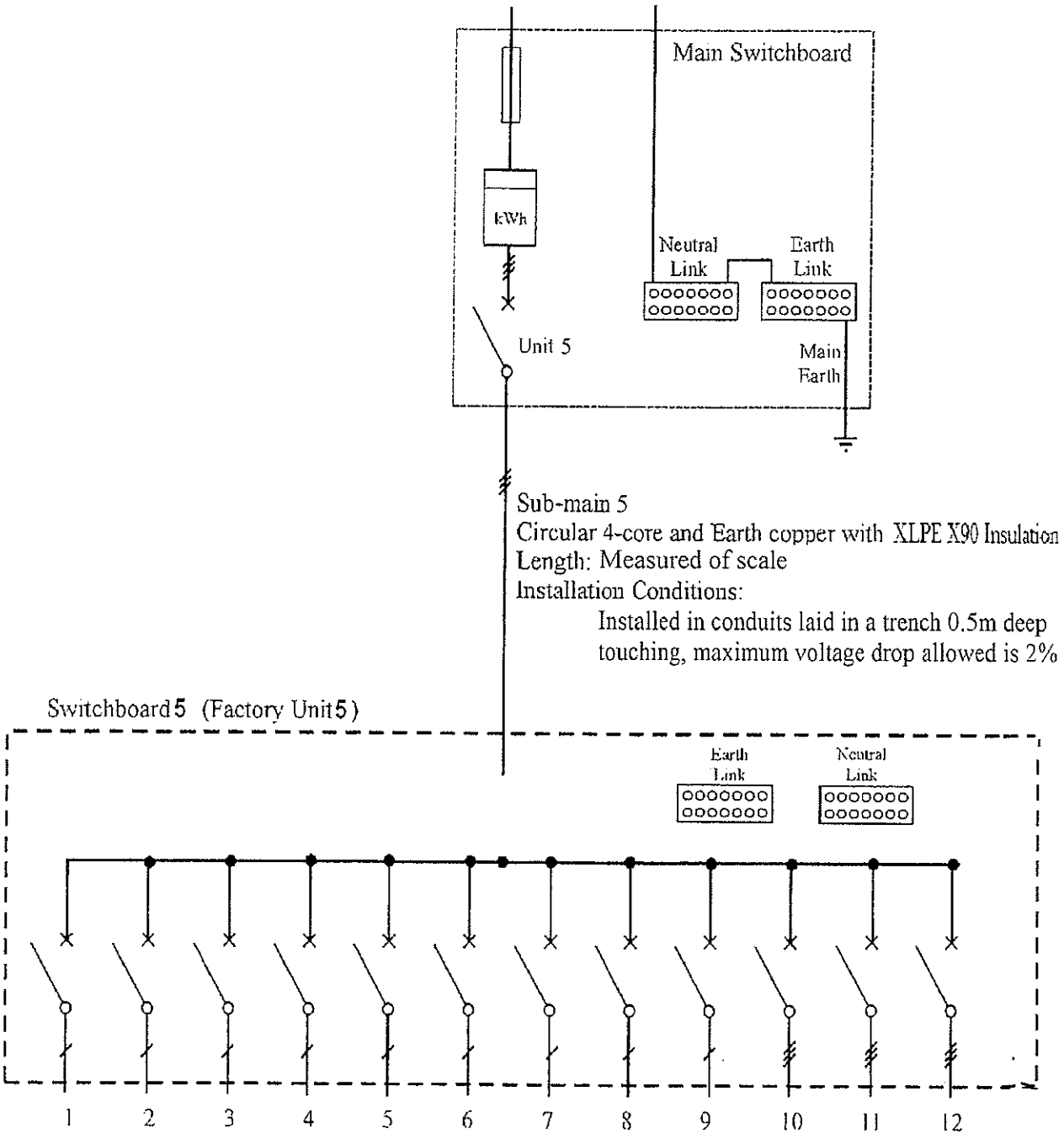



**Figure 3**

| Circuit | Description | Quantity | Fitting rating |
|---|---|---|---|
| 1 | Fluorescent lighting office | 12 | 0.7A |
| 2 | Fluorescent lighting factory | 14 | 0.7A |
| 3 | Air extraction fan | 1 | 1.5hp 8A |
| 4 | Single phase SO office | 12 double | 10A |
| 5 | Single phase SO factory | 10 double | 10A |
| 6 | Single phase SO factory | 3 | 15A |
| 7 | Single phase SO factory | 1 | 25A |
| 8 | Three phase SO factory | 1 | 40A |
| 9 | Drill press | 1 | 12.5A |
| 10 | Compressor | 1 | 20A |
| 11 | 6KW Air conditioner | 1 | 6A/phase |
| 12 | 6KW Instantaneous HWS | 1 | 6KW |

could be 1Ø or 3Ø

could be 1Ø or 3Ø

**Table 1**

**QUESTION 2.** **(4 Marks)**

(a) If sub-main 5 supplying factory unit 5 in **Error! Reference source not found.** has a maximum demand of 53A, determine the minimum conductor size based on current carrying capacity when installed as shown in **Error! Reference source not found.** and **Error! Reference source not found.**. (2marks)

T26(2) 4ccts touching 0.79 53/0.79=67A, T13 col 14 = 16mm$^2$ @ 83A

other references T2(4) Item 4 → T13 Col 14 → T26(2)

Note: no derating used T13 Col 14 → 10 mm$^2$ at 64A (1 mark)

(b) If the sub-main to factory unit 1 in **Error! Reference source not found.** was installed close to the roof where the ambient air temperature could reach 55$^0$C, what de-rating factor would apply to the cable? (2marks)

Insulation XLPE x 90 @ 55°C

**T27(1) de-rating factor = ~~0.88~~** 0.81

**QUESTION 3.** **(3 Marks)**

The three-phase 230/400V consumer main to the block of factory units consists of SDI cables having circular copper conductors. The active conductors are 150mm$^2$. The supply Authority nominates the fault level at the point of supply 25kA. The soil resistivity is very low. The cable route length may be measured off the plan to the edge of the main switchboard. Calculate the theoretical fault current active to earth at the main switchboard.

Ref T34 (90°C)

**Zsource = V/I = 230/25,000= 0.0092ohms**

**Zcm= 0.16x13m/1000=0.0028ohms** OR Zcm at 75°C

$Z_{cm} = 0.153 \times \frac{12}{1000} = 0.00183\Omega$

**Ztotal= 0.0092+0.0028=0.012ohms**

$Z_T = 0.0092 + 0.0018$

**Ifault= V/Z** **230/0.012=19.2kA** **Ifault=19.2kA**

$I_{fault} = \frac{230}{Z_T} =$ 20.8KA

**QUESTION 4.** **(6 Marks)**

**Calculate the maximum demand of the three-phase sub-main to unit five.**

| Load group | Load description | Qty | Calculation | Demand A phase | Demand B phase | Demand C phase |
|---|---|---|---|---|---|---|
| A | lights | 12 | 12x 0.7=8.4A | 8.4 | | |
| A | lights | 14 | 14x0.7=9.8A | | | 9.8 |
| D | Exhaust fan | 1 | 8Ax0.5 | | | 4 or 8 |
| Bi | 10A SO | 24 | (1000+100x23)/230= | 14.3 | | |
| Bi | 10A SO | 20 | (1000+750x19)/230= | | 66.3 | |
| Biii | 15A SO | 3 | 3x15x0.75 | | | 33.75 |
| Biii | 25A SO | 1 | 25x0.75 | 18.75 | | |
| Biii | 40A SO | 1 | | 40 | 40 | 40 |
| D | Drill | 1 | 12.5x0.75 | 9.4 or 3Ø | 9.4 | 9.4 |
| D | Compressor | 1 | 20 Note: could be 1Ø | 20 or Ø | 20 | 20 or Ø |
| C | Air cond | 1 | 6x0.75 | 4.5 | 4.5 | 4.5 |
| C | HWS | 1 | 6000/(3x230) Note: could be 1Ø | 8.7 | 8.7 | 8.7 |
| | | | Total | 124 | 140 | 121 |

Kor

Ref: Tc2 Col3

or 26.1 on 1 phase

The maximum demand of unit 5 is ___**140A**_____A per phase (Note to marker- subtract 1 mark for each incorrect load group).

**QUESTION 5.** **(2 Marks)**

If the maximum demand of the sub-main to unit 5 in **Error! Reference source not found.** was 110A, what would be the minimum size of the active, neutral and earth conductors, based on current carrying capacity, for a V90 multi-core cable having copper conductors, installed in an underground duct together with three other sub-mains, when protected by a 120A type D circuit breaker? Derating table ~~26.2=0.79~~, required CCC =120/0.79=152A Table 9 = 50mm$^2$ T22 = 0·65

120/0·65 = 184A

Size based on current carrying capacity = ~~50mm$^2$~~ (Note to marker- No part marks for this question). 95mm$^2$ @ 210A.

Ref T2(4) T12 Col 16 → T22

**QUESTION 6.** **(3 Marks)**

If the maximum demand of unit 5 in **Error! Reference source not found.** was 85A, and the sub-main supplying unit 5 is X90 multi-core cables having 50mm$^2$ circular copper conductors, would the voltage drop be within the specified limit of 2.0% if the length of the sub-main is 50 metres?

ref: T42

Vd=VcLI/1000

=0.868x50x85/1000= 3.7V

0·868 mV/Am

T42 X90 mV/Am=0.868 ~~2% x 230 = 4.6V~~ 2% x 400V = 8V

Actual voltage drop___3.7V____(2marks). (Note to marker- No part marks for this part of the question).

8V

Within 2% limit_3.7~~≤4.6V~~__yes within limit____(1mark)

**QUESTION 7.** **(3 Marks)**

If the sub-main cable to unit 5 in **Error! Reference source not found.** was protected by an 85A Type D circuit breaker, calculate the tripping time for circuit breaker if the source impedance at the MSB is 0.015ohms.

V90 copper cables 50m long resistance= 50x0.471/1000= 0.023ohms

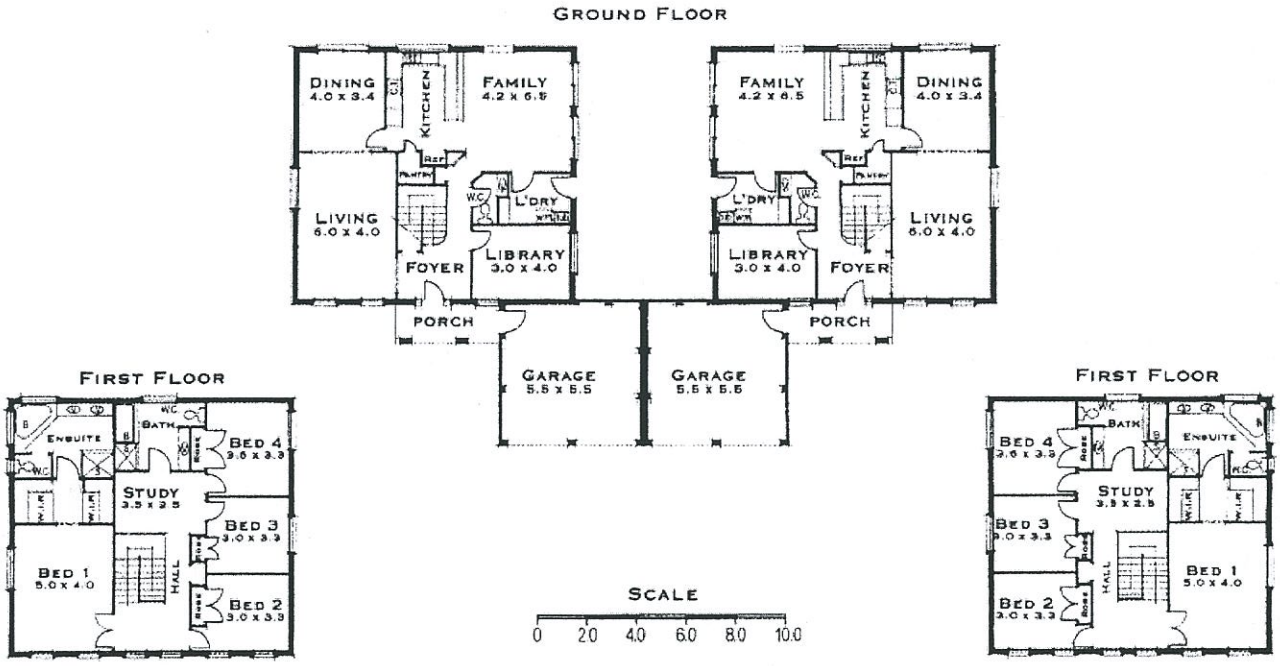
Ztotal =0.015+0.023=0.038ohms Isc = V/Zt =230/0.038=6kA

T52 Max temp =250deg T51, K = 131 I= 12.5x85=1065.25A

$T=K^2S^2/I^2 = 131^2 50^2/6000^2 =$ 1.21sec

Tripping time__1.21sec___(2marks)

Is the time within the maximum allowed tripping time for a sub-main? _Yes__(1mark)




**QUESTION 8 (5marks)**

**Calculate the maximum demand for one of the above duplex dwellings with the following load.**

| Circuit | Description | Quantity | Rating |
|---|---|---|---|
| 1 | Low voltage down lights | 20 | 50W |
| 2 | Low voltage down lights | 20 | 50W |
| 3 | Compact fluorescents | 10 | 15W |
| 4 | Single phase socket outlets | 16 double | 10A |
| 5 | Single phase socket outlets | 20 double | 10A |
| 6 | Single phase socket outlets | 1 | 15A |
| 7 | Single phase cook top (20A SO) | 1 | 7.8KW |
| 8 | Single phase oven/grill (20A SO) | 1 | 5.6kW |
| 9 | Security system and smoke alarm | 1 | 0.5A |

| | | | |
|---|---|---|---|
| 10 | Single phase air conditioner | 1 | 12.6A |
| 11 | Solar booster element (controlled load) | 1 | 3.6KW |

Ref: Table C1 Col 2.

| Load group | Load description | Qty | Calculation | Demand |
|---|---|---|---|---|
| Ai | lights | 52 | 3+2+2 | 7 |
| Bi | 10A SO | 72 | 10+5+5+5 | 25 |
| Bii | 15A SO | 1 | 10 | 10 |
| C | cooking | 2 | (7.8+5.6kW)x0.5/230 | 29.1 |
| D | Air Cond | 1 | 12.6x0.75 | 9.45 |
| F | HW booster | 1 | 3600/230 | 15.65 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**Maximum demand ___96.2A_____**

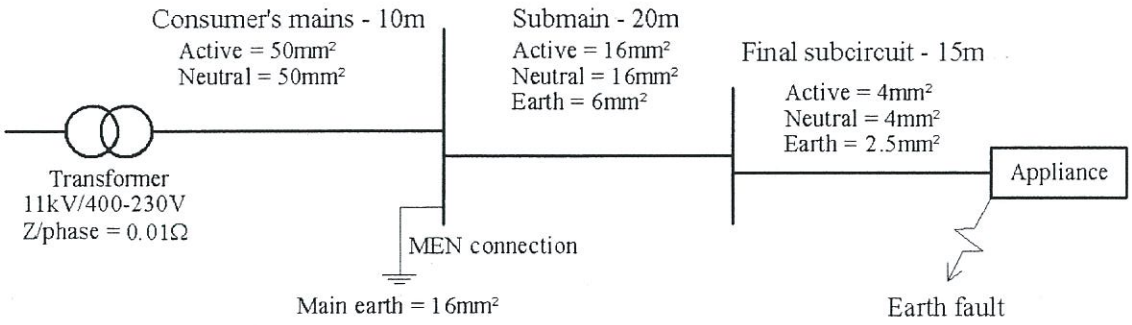
(Note to marker- subtract 1 mark for each incorrect load group).

(5 marks)

**QUESTION 9 (5marks)**

The diagram below shows a single line diagram representing a supply transformer, consumer mains XLPE X90 to a main switchboard, sub-main XLPE X90 to a distribution board, and a final sub-circuit V75 to an appliance. An earth fault of zero impedance occurs at the appliance. Calculate the total fault loop impedance.

(assume the fault current returns to the supply via the consumers main's neutral )




**T35**

3.93

**Zs=0.01Ω** Zcm=0.494x0.01x2=0.00988 Ω, Zsm=1.47x0.02+~~5.88~~x0.02=~~0.147~~ Ω 0.108Ω

Zfsc=5.61x0.015+9.01x0.015=0.2193 Ω Ztotal=~~0.37618~~ Ω = 0.34718Ω

~~**Ifault=V/Zt = 230/0.37618= 611.4A**~~ Question doesn't ask for $I_{FAULT}$ (Fault current)

---

Alternate Answer * Assume CM's are single core use Table 34 90°

$Z_s$ = 0.01Ω

$Z_{cm}$ $X_{90}$ (Act + Neutral) = $\frac{10}{1000} \times 0.494 \times 2$ = 0.00988Ω

Assume SM and fsc are multicore ref T35

$Z_{sm}$ $X_{90}$ (Act) = $\frac{20}{1000} \times 1.47$ = 0.0294Ω

$Z_{sm}$ $X_{90}$ (earth) = $\frac{20}{1000} \times 3.93$ = 0.0786Ω

$Z_{fsc}$ V75 Act = $\frac{15}{1000} \times 5.61$ = 0.08415Ω

$Z_{fsc}$ V75 (earth) = $\frac{15}{1000} \times 9.01$ = 0.13515Ω

$Z_{TOTAL}$ = 0.34718Ω

# SECTION D – (15 Marks)

**INSTRUCTION: The question in this section requires some simple drawing. Ensure that the drawing is neat and legible. The use of pencil on the drawing is acceptable in this section only.**

**Figure 5 shows the time-current characteristic curves for type 'C' and type 'D' thermal-magnetic circuit breakers of a particular manufacturer. Use this information to answer questions 1 and 2 of this section.**

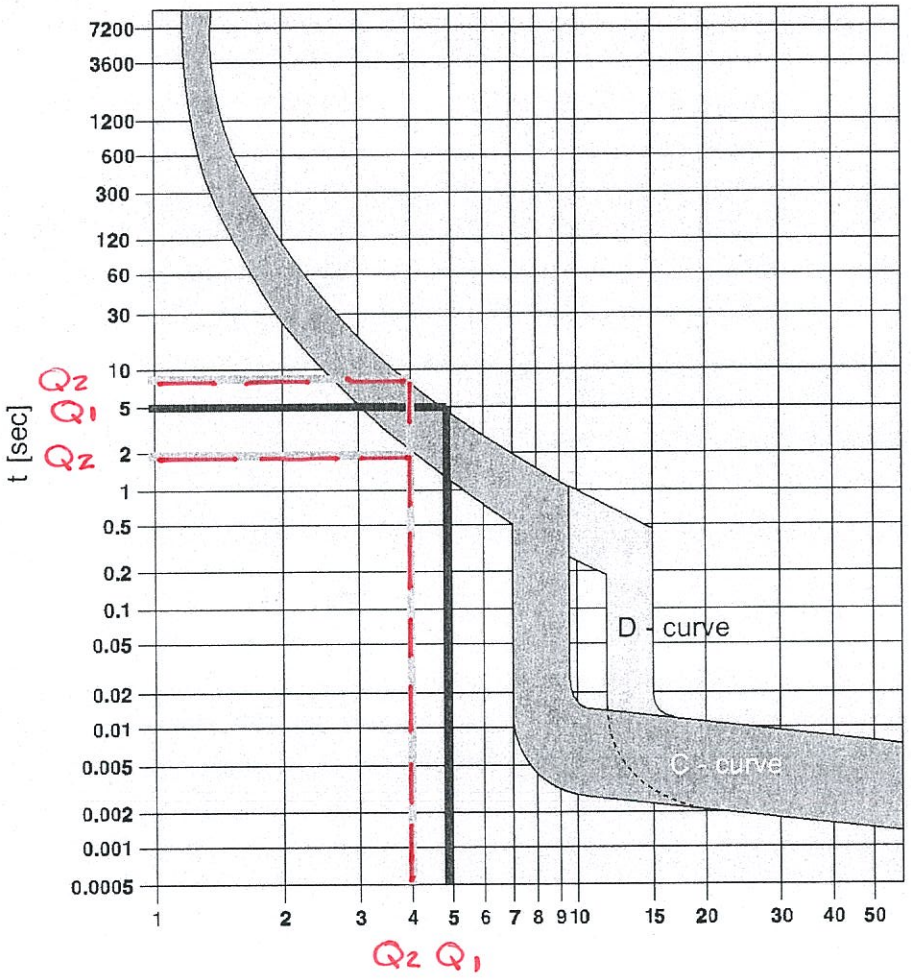



*Figure 5*

## SECTION D – (Cont'd)

**QUESTION 1. (3 Marks)**

A three phase motor with an earthed metallic frame is to be permanently installed in a fixed position and connected via an isolation switch. The final sub-circuit to the motor is to be protected by a 40 Amp type 'D' thermal-magnetic circuit breaker. Using the characteristic curve shown in Figure 1, determine the value of current required to **ensure** the protective device operates within the specified time required by AS3000, in order to protect against indirect contact.

From graph $I/I_N = 5$ $\therefore I = 5I_N$

5x40A = 200A

Note: fixed equipment trip time = 5secs.

**QUESTION 2. (2 Marks)**

A circuit is to be protected by a 50 Amp type 'C' circuit breaker. Using the circuit breaker characteristic curve of Figure 1, determine the approximate minimum and maximum operating times for a fault current of 200 Amps.

Minimum ____2_____ seconds

Maximum ____8_____ seconds

$I/I_N = 200/50 = 4I/I_N$

## SECTION D – (Cont'd)

**QUESTION 3. (5 Marks)**

The following diagram represents the main switchboard of a domestic installation. For simplification, only a small selection of equipment has been shown.

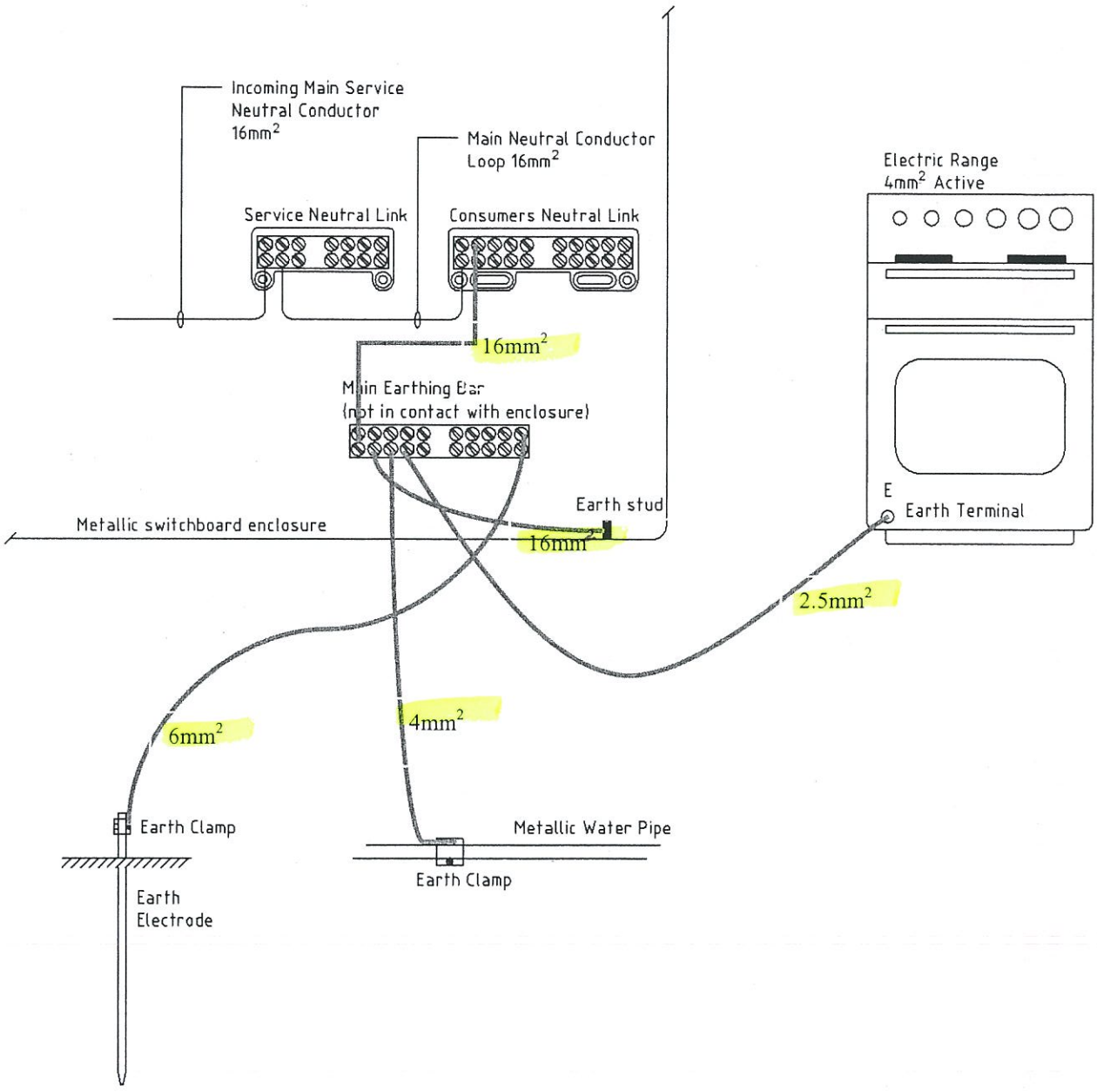
The unprotected consumer mains entering the main switchboard consist of 16mm$^2$ active and neutral conductors. The consumer mains are single insulated within the metallic enclosure.

On the following diagram, neatly draw in all necessary earthing and equipotential bonding conductors required to complete an M.E.N system of earthing.

The incoming water service is electrically continuous between the building interior and the ground.

Based on the given information, determine the minimum size of all earthing conductors, which is to be shown alongside each conductor (active and neutral conductors need not be shown).

# SECTION D – (Cont'd)




(Note to marker- Subtract 1 mark for each incorrect connection or cable size).

## SECTION D – (Cont'd)

**QUESTION 4. (5 Marks)**

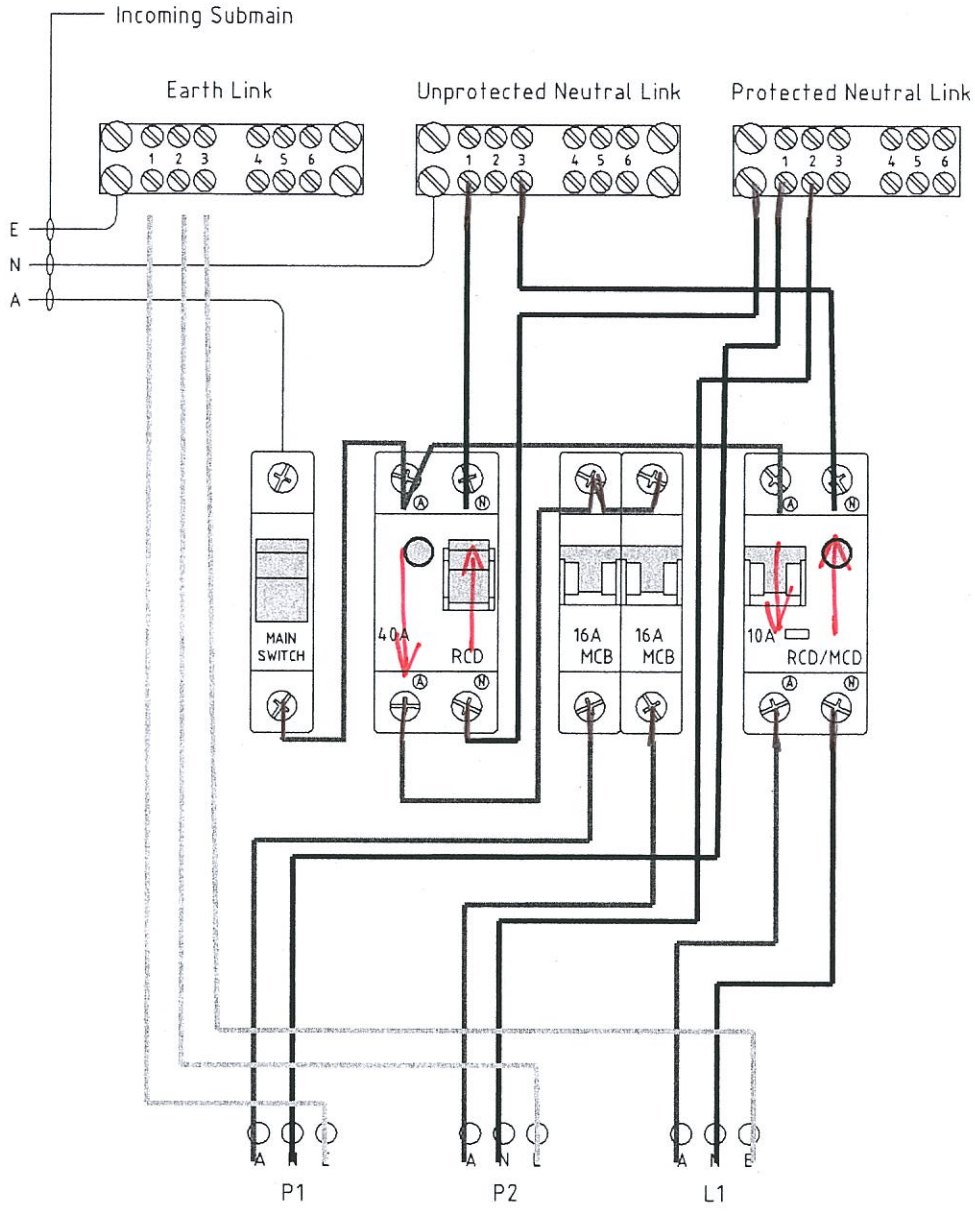
The following diagram represents selected items contained within a domestic electrical distribution board.

Neatly draw in all **active**, **neutral** and **earth** conductors necessary for the safe and proper operation of the circuits.

Power circuits P1 and P2 will be individually protected by their own 16A MCB. Both circuits (P1 & P2) will also have additional protection by a common 40A 2 pole RCD.

Lighting circuit L1 is to be protected by a 10A combination RCD/MCB.




(Note to marker- Subtract 1 mark for each incorrect connection).

3 Dec 2009

Name: KEY

College: WOLLG

# ANSWER SHEET – Section A (Multi-choice Questions)

**Module - 6077AC** **Examination Date: 3rd December 2009**

**Instructions:**

- Enter your name and college on this sheet.
- Place an **X** in box of your choice. If you make a mistake- circle your answer (X) and choose again.
- For your convenience you can remove this page while you answer Section A. **Remember to re-attach it** to the paper when you hand it in.

| Question | a | b | c | d |
|---|---|---|---|---|
| 1 | | | X | |
| 2 | | | | X |
| 3 | | | X | X |
| 4 | X | | | |
| 5 | | | X | |
| 6 | | X | | |
| 7 | | | X | X |
| 8 | | | X | |
| 9 | | | | X |
| 10 | X | | | |
| 11 | | X | | |
| 12 | | | | X |
| 13 | | | X | |
| 14 | | X | | |
| 15 | | | X | |
| 16 | | X | | |
| 17 | | X | | |
| 18 | | | X | |
| 19 | X | | | |
| 20 | | | X | |
| **Totals** | | | | |
| **Total Correct Section A** | | | | |

2 answers

Reference AS/NZS 3000
2.4.4.1 NSW S&IR
1.4.65 AS/NZS 3000
1.4.75 AS/NZS 3000
General knowledge
1.4.95 & 1.4.98 ELV AS/NZS 3000
2.2.2c) AS/NZS 3000
2.3.3.4 AS/NZS 3000
2.3.3.3a) AS/NZS3000
2.3.2.2.2 AS/NZS3000
General knowledge
General knowledge
C4.1 AS/NZS 3000
General knowledge
General knowledge
5.4.6.3 AS/NZS 3000
Table 3.6 AS/NZS 3000
Table 3.8 AS/NZS 3000
4.12.5.1 AS/NZS3000
5.3.3.2(a) AS/NZS3000
8.3.6.1 AS/NZS 3000
500V +20% -10%

**Total Marks Section A:** ..... /20

Note: The symbols used on this sheet follow AS1046 pt 1. There are alternate recognised symbols in use. The list does not contain every equation used in the course. Transposition of equations will be necessary to solve problems

$$Q = It \qquad v = \frac{s}{t} \qquad a = \frac{\Delta v}{t}$$

$$F = ma \qquad W = Fs \qquad W = mgh$$

$$W = Pt \qquad \eta\% = \frac{output}{input} \times \frac{100}{1} \qquad I = \frac{V}{R}$$

$$P = VI \qquad P = I^2 R \qquad P = \frac{V^2}{R}$$

$$R_2 = \frac{R_1 A_1 l_2}{A_2 l_1} \qquad R_h = R_c(1 + \alpha \Delta t) \qquad R = \frac{\rho l}{A}$$

$$R_T = R_1 + R_2 + R_3 \qquad V_T = V_1 + V_2 + V_3 \qquad \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$I_T = I_1 + I_2 + I_3 \qquad V_2 = V_T \frac{R_2}{R_1 + R_2} \qquad I_2 = I_T \frac{R_1}{R_1 + R_2}$$

$$R_x = \frac{R_A R}{R_B} \qquad C = \frac{Q}{V} \qquad \tau = RC$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \qquad C_T = C_1 + C_2 + C_3 \qquad C = \frac{A \varepsilon_o \varepsilon_r}{d}$$

$$F_m = IN \qquad H = \frac{F_m}{l} \qquad B = \frac{\Phi}{A}$$

$$\Phi = \frac{F_m}{S} \qquad S = \frac{l}{\mu_o \mu_r A} \qquad V = N \frac{\Delta \Phi}{\Delta t}$$

$$e = Blv \qquad L = \frac{\mu_o \mu_r A N^2}{l} \qquad L = N \frac{\Delta \Phi}{\Delta I}$$

$$V = L \frac{\Delta I}{\Delta t} \qquad \tau = \frac{L}{R} \qquad F = Bil$$

$$T = Fr \qquad E_g = \frac{\Phi Z n P}{60a} \qquad P = \frac{2\pi n T}{60}$$

$$t = \frac{1}{f} \qquad f = \frac{np}{120} \qquad V = 0.707 V_{max}$$

$$I = 0.707 I_{max} \qquad V_{ave} = 0.637 V_{max} \qquad I_{ave} = 0.637 I_{max}$$

$$v = V_{max} \sin \phi \qquad i = I_{max} \sin \phi \qquad I = \frac{V}{Z}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \qquad X_L = 2\pi f L \qquad X_C = \frac{1}{2\pi f C}$$

$$\cos \phi = \frac{P}{S} \qquad \cos \phi = \frac{R}{Z} \qquad S = \sqrt{P^2 + Q^2}$$

$$S = VI \qquad P = VI \cos \phi \qquad Q = VI \sin \phi$$

$$f_o = \frac{1}{2\pi\sqrt{LC}} \qquad V_L = \sqrt{3}V_P \qquad I_L = \sqrt{3}I_P$$

$$S = \sqrt{3}V_L I_L \qquad P = \sqrt{3}V_L I_L \cos\phi \qquad Q = \sqrt{3}V_L I_L \sin\phi$$

$$\tan\phi = \sqrt{3}\left(\frac{W_2 - W_1}{W_2 + W_1}\right) \qquad Q = mC\Delta t$$

$$V' = 4.44\Phi f N \qquad \frac{V_1}{V_2} = \frac{N_1}{N_2} \qquad \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

$$N_{syn} = \frac{120f}{p} \qquad s\% = \frac{(n_{syn} - n)}{n_{syn}} \times \frac{100}{1} \qquad f_r = \frac{s\% \times f}{100}$$

$$V_{reg}\% = \frac{(V_{NL} - V_{FL})}{V_{FL}} \times \frac{100}{1} \qquad V_{reg}\% = \frac{(V_{NL} - V_{FL})}{V_{NL}} \times \frac{100}{1} \qquad T = \frac{\Phi ZIP}{2\pi a}$$

$$I_{ST} = \frac{1}{3} \times I_{DOL} \qquad T_{ST} = \frac{1}{3} \times T_{DOL} \qquad I_{ST} = \frac{V_{ST}}{V} \times I_{DOL}$$

$$T_{ST} = \left(\frac{V_{ST}}{V}\right)^2 \times T_{DOL} \qquad I_{motor\,st} = \frac{\%TAP}{100} \times I_{DOL} \qquad I_{line\,st} = \left(\frac{\%TAP}{100}\right)^2 \times I_{DOL}$$

$$E = \frac{\Phi_v}{A} \qquad E = \frac{I}{d^2} \qquad \eta_v = \frac{\Phi_v}{P}$$

$$V_L = 0.45V_{ac} \qquad V_L = 0.9V_{ac} \qquad V_L = 1.17V_{phase}$$

$$V_L = 1.35V_{line} \qquad PRV = \sqrt{2}V_{ac} \qquad PRV = 2\sqrt{2}V_{ac}$$

$$PRV = 2.45V_{ac} \qquad V_{ripple} = \sqrt{2}V_{ac} \qquad V_{ripple} = 0.707V_{phase}$$

$$V_{ripple} = 0.1895V_{line}$$