basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

# ELECTRICAL TECHNOLOGY

## GUIDELINES FOR PRACTICAL ASSESSMENT TASKS

## 2017

**These guidelines consist 76 pages.**

## TABLE OF CONTENTS

## 1. INTRODUCTION

The 16 Curriculum and Assessment Policy Statement subjects which contain a practical component all include a practical assessment task (PAT). These subjects are:

- AGRICULTURE: Agricultural Management Practices, Agricultural Technology
- ARTS: Dance Studies, Design, Dramatic Arts, Music, Visual Arts
- SCIENCES: Computer Applications Technology, Information Technology
- SERVICES: Consumer Studies, Hospitality Studies, Tourism
- TECHNOLOGY: Civil Technology, Electrical Technology, Mechanical Technology and Engineering Graphics and Design

A practical assessment task (PAT) mark is a compulsory component of the final promotion mark for all candidates offering subjects that have a practical component and counts 25% (100 marks) of the end-of-year examination mark. The PAT is implemented across the first three terms of the school year. This is broken down into different phases or a series of smaller activities that make up the PAT. The PAT allows for learners to be assessed on a regular basis during the school year and it also allows for the assessment of skills that cannot be assessed in a written format, e.g. test or examination. It is therefore important that schools ensure that all learners complete the practical assessment tasks within the stipulated period to ensure that learners are resulted at the end of the school year. The planning and execution of the PAT differs from subject to subject.

Practical assessment tasks are designed to develop and demonstrate a learner's ability to integrate a variety of skills in order to solve a problem. The PAT also uses a technological process to inform the learner what steps needs to be followed to derive a solution for the problem.

The 2017 PAT has three focus areas with projects and simulations in each of the following fields:

- Electrical
- Electronics
- Digital Electronics

The PAT task consists of four simulations and a practical project. The teacher may choose any of the practical projects and use a combination of the simulations available.

The teacher has to apply assessment on an on-going basis at the same time that the learner is developing the required skills. Four simulations should be completed by the learners, in addition to the manufacturing of a practical project.

The PAT incorporates all the skills the learner developed from Grades 10, 11 and 12. The PAT ensures that all the different skills will be acquired by learners on completion of practical work, that is electrical, analogue and digital electronics as well as the correct use of tools and instruments.

**Requirements for presentation**

A learner must present the following:

- PAT file with all the evidence of simulations, design and prototyping
- Practical project with:
  - Enclosure
    - The file must include a design.
    - The enclosure and the design must match.
    - No cardboard boxes are allowed.
    - Plastic and metal enclosures are acceptable.
    - The enclosure should be accessible for scrutiny inside.
    - Lids that are secured with screws are preferred.
  - Circuit board
    - The file should include the PCB design.
    - The PCB must be mounted inside the enclosure in such a manner that it can be removed for scrutiny.
    - Switches, potentiometers, connectors and other items must be mounted.
    - Wiring must be neat and bound/wrapped.
    - Wiring must be long enough to allow for the PCB to be removed and inspected with ease.
  - Logo and Name
    - The file should contain the logo and name design.
    - Logo and name must be prominent on the enclosure.

The PAT will have a financial impact on the school's budget and school management teams are required to make provision to accommodate this particular expense.

PAT components and other items must be acquired timely for use by the learners before the end of the first term at the start of the academic year.

It is the responsibility of the HOD to ensure that the teacher is progressing with the PAT from the start of the school year.

Provincial departments are responsible for setting up moderation timetables and consequently PATs should be completed in time for moderation.

## 2. TEACHER GUIDELINES

### 2.1 How to administer the PATs

Teachers must ensure that learners complete the simulations required for each term. The project should be started in January in order to ensure its completion by August. All formal assessment is the teacher's responsibility.

The PAT should be completed during the first three terms and must be ready at the start of PAT moderation. Teachers must make copies of the relevant simulations and hand them to learners at the beginning of each term.

**The PAT must not to leave the workshop and must be kept in a safe place at all times when the learner is not working on it.**

The weightings of the PAT must be adhered to and teachers are not allowed to change weightings for the different sections.

### 2.2 How to mark/assess the PATs

The PAT for Grade 12 is externally set and moderated, but internally assessed. All formal assessment will be done by the teacher. The PAT must be moderated by the following persons:

The teacher is required to produce a **working model and model answer file** which sets the baseline for assessment at a Highly Competent Level for every project choice exercised by the learners. This file must include all the simulations with answers the teacher has done him-/herself. The teacher will use the model answers and project to assess the simulations and projects of the learners.

Once a rubric has been completed by the teacher, assessment will be deemed to be complete. **No re-assessment will be done once the rubrics have been completed** and captured by the teacher. Learners must ensure that the work is done to the standard required before the teacher finally assesses the PAT during each stage of completion.

## 2.3 PAT assessment management plan

The assessment plan for the PAT is as follows:

| TIME FRAME | ACTIVITY | RESPONSIBILITY |
|---|---|---|
| October–December 2016 | Preparation for PAT 2017 | Teacher – Builds the models and works out the model answers for the simulations for 2017. Identify shortages in tools, equipment and consumable items for simulations which must be procured in 2017.<br>SMT – Receive procurement requests from teachers and process payments for the acquisition of required items. |
| January–March 2017 | Simulations 1 and 2 | Teacher – Copies and hands out simulations.<br>Learners – Completes simulations.<br>Teacher – Assesses simulations.<br>HOD – Checks if tasks have been completed and marked by the teacher before the holiday. |
| January 2017 | PAT Project: Procurement | Teacher – Obtains quotations for PAT projects.<br>Principal – Approves PAT procurement for PAT projects.<br>Teacher – Ensures that PAT projects are ordered and delivered.<br>HOD – Checks up on teacher to see if the process is being adhered to. |
| February 2017 | PAT Project: Learners commence with project. | Teacher – Ensures that there is secure storage for PAT projects.<br>Teacher – Hands out and takes in PAT projects.<br>Teacher – Includes practical sessions for learners to complete PAT project every week.<br>Learners – Commence with completion of the PAT project.<br>HOD – Checks on teacher to ensure that practical workshop sessions take place on a weekly basis. |
| April–June 2017 | Moderation of Simulations 1 and 2 | District Subject Facilitator/Subject Specialist will visit the school and moderate Simulations 1 and 2. 10% of learners' work is moderated. |
| April–June 2017 | Simulations 3 and 4 | Teacher – Copies and hands out simulations.<br>Learners – Completes simulations.<br>Teacher – Assesses simulations.<br>HOD – Checks if tasks have been completed and marked by the teacher before the holiday. |
| April–June 2017 | PAT project: Learners continue with project | Teacher – Ensures that there is secure storage for PAT projects.<br>Teacher – Hands out and takes in PAT projects.<br>Teacher – Includes practical sessions for learners to complete PAT project every week.<br>Learners – Continue with completion of the PAT project.<br>HOD – Checks on teacher to ensure that practical workshop sessions take place on a weekly basis. |
| July holiday 2017 | PAT intervention | Learners that are behind on the PAT are required to complete the project during this holiday. |
| July–August 2017 | Moderation of Simulations 3 and 4 | District Subject Facilitator/Subject Specialist will visit the school and moderate Simulations 3 and 4. Different learners from the previous term. 10% of learners' work is moderated. |
| July–August 2017 | PAT project: completion | Teacher – Ensures that there is secure storage for PAT projects.<br>Teacher – Hands out and takes in PAT projects.<br>Teacher – Completes the PAT project with learners and compiles the PAT file.<br>Learners – Completes the PAT project and file.<br>HOD – Checks to see that 100% of PAT files and project are completed and assessed |
| September–October 2017 | PAT moderation | PAT projects are moderated by subject facilitators/subject specialists from the province and learners are available to demonstrate skills. 10% of learners are moderated at random. |

## 2.4 Moderation of the PATs

Provincial moderation of each term's simulations will start as early as the following term. Simulations 1 and 2 should be moderated as soon as the second term starts. Similarly simulations 3 and 4 will be moderated in July. The project, however, will only be moderated on completion.

During moderation of the PAT the learner's file and project must be presented to the moderator.

The moderation process is as follows:

- During moderation learners are randomly selected to demonstrate the different simulations. All four simulations will be moderated.
- **The teacher is required to build an exemplar model for each project type chosen for the school.**
- **This model must be on display during moderation.**
- **The teacher's model forms the standard of the moderation at Level 4 (Highly Competent).**
- **Level 5 assessments must exceed the model of the teacher in skill and finishing.**
- Learners being moderated will have access to their file during moderation and may refer to the simulations they completed earlier in the year.
- Learners may not ask assistance from other learners during moderation.
- All projects and files must be on display for the moderator.
- **If a learner is unable to repeat the simulation or cannot produce a working circuit during moderation, marks will be deducted and circuits assessed as not being operational.**
- The moderator will select, at random, not fewer than **two projects** (not simulations) and the learners involved will have to explain how the project was manufactured.
- Where required, the moderator should be able to call on the learner to explain the function and principles of operation and also request the learner to exhibit the skills acquired through the simulations for moderation purposes.
- On completion, the moderator will, if needed, adjust the marks of the group upwards or downwards, depending on the outcome of moderation.
- Normal examination protocols for appeals will be adhered to if a dispute arises from adjustments made.

## 2.5 Absence/Non-submission of tasks

In the absence of a PAT mark in Electrical Technology, without a valid reason, the learner will be given three weeks before the commencement of the final end-of-year examination to submit the outstanding task(s). Should the learner fail to fulfil the outstanding PAT requirement such a learner will be awarded a zero for that PAT component. The final mark for the PAT will be adjusted for promotion purposes in terms of the completed tasks.

A learner's results are regarded as incomplete if he/she does not offer any component of the PAT. He/She will be given another opportunity based on the decision of the Head of the Assessment Body.

## 2.6 Simulations

Simulations are circuits, experiments and tests which the learner will have to build, test and measure and do practically as part of the development of practical skills. These skills have to be illustrated to the external moderator who visits the school at intervals during the school year.

Teachers who use simulation programs on computer are welcome to use them for the learners to practise on. However, it is required that the circuit be built using real components and that measurements be made with actual instruments for the purposes of assessment and moderation.

The correct procedure to complete simulations is outlined below for teachers and school management teams who are responsible for the implementation of the PAT in Electrical Technology.

**Step 1:** The teacher will choose simulations from the examples provided.
**Step 2:** Compile a list of the components needed for every simulation. Add extra components as these items are very small and you will need extras because they are lost or damaged very easily when learners work with them.
**Step 3:** Contact three different electronics component suppliers for comparative quotations.
**Step 4:** Submit the quotations to the SMT for approval and procurement of the items.
**Step 5:** Store the components. Collate items for each simulation, thus making it easier to distribute and use during practical sessions. Ensure that different values of components do not mix as this will lead to components being used incorrectly. This could damage the component and, in extreme cases, the equipment used.
**Step 6:** Copy the relevant simulations and hand them out to learners at the start of the term.

Teachers are allowed to adjust circuits and component values to suit their environment/resource availability.

Teachers are required to develop a set of model answers in the teacher's portfolio.

Moderators will use the teacher's model answers and artefact when moderating.

## 2.7 Projects

The projects described below are suggested construction projects teachers can choose for their learners. These projects are based on circuits provided by schools and subject advisors. The projects are based on working prototypes and require careful construction in order for it to operate correctly.

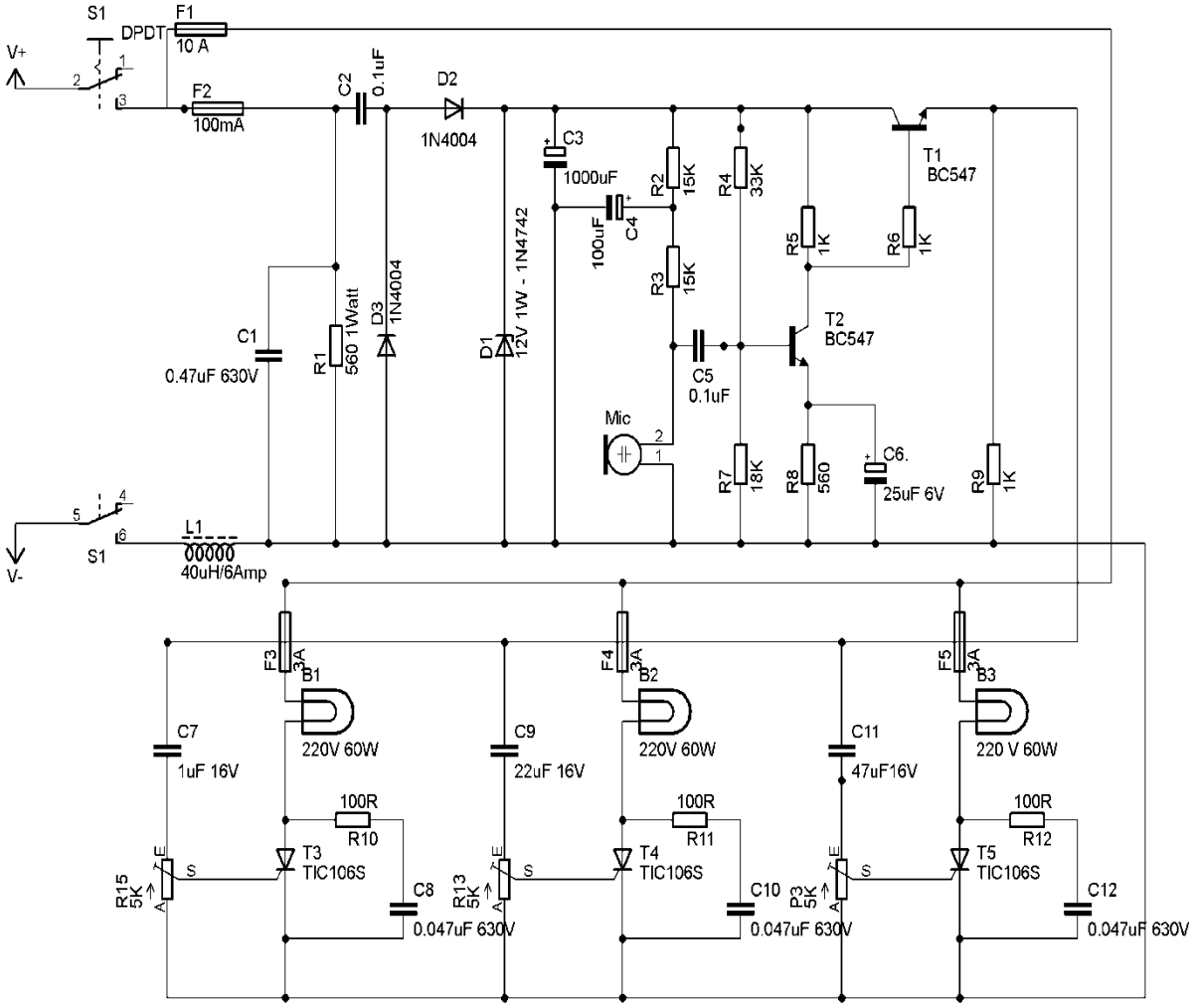
Projects vary in cost and teachers must ensure that the projects chosen fall within the scope of the school's budget.

Once the teacher has decided on a circuit, he/she must construct the prototype. Thereafter copies of the circuit provided can be made and distributed to learners. They MUST redraw these circuits in their portfolios correctly.

The description of the operation of the circuits is NOT complete. Learners are required to interrogate the function of the components in the circuit provided. They should elaborate on the purpose of components in the circuit. It is recommended that learners investigate similar circuits available on the Internet and in the school library/workshop reference books.

## Electrical Project: Sound-to-light Controller (Option 1 of 6)

**WARNING:** Some parts in the circuit board are subject to lethal potential because the device is connected to 230 V AC. When plugging in the project, place it in a plastic or wooden box to prevent the circuit from shocking you. Avoid connecting this circuit to other appliances (e.g. to the output of an amplifier by means of a cable) because of the absence of a mains transformer. Use only the microphone in the main case to pick up the sound.




| COMPONENT LIST | |
|---|---|
| R1 | 560 kΩ 1 W |
| R2, R3 | 15 K ¼ W |
| R3 | 33 K□¼ W |
| R□, R6, R9 | 1 kΩ ¼ W |
| R7 | 18 K ¼ W |
| R8 | 560 Ω ¼ W |
| P1, P2, P3 | 5 K Pot |
| C | 0,47 uF 630 V |
| C2, C5 | 0,1 µF 220 V |
| C3 | 1 000 µF 16 V electrolytic |
| C4 | 100 µF 16 V |
| C6 | 25 µF 16 V |
| C7 | 1 µF 16 V |
| S1A & S1B | Double-pole switch |
| T1, T2 | BC 547 |

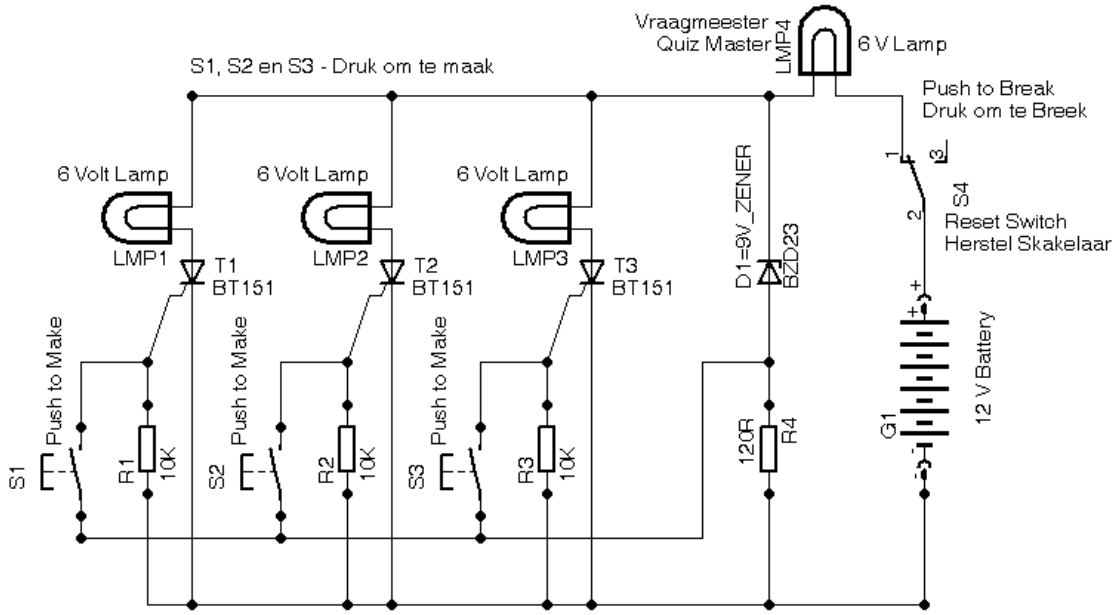
| COMPONENT LIST | |
|---|---|
| C□, C□0, C12 | 0,047 µF |
| C9 | 22 µF 16 V |
| C11 | 47 µF 16 V |
| D1, D2 | 1N4004 |
| D3 | 1N4742 1 W |
| F1 | 10 A fuse 220 V |
| F2 | 100 mA fuse 220 V |
| F3, F4, F5 | 220 V 3 A fuse |
| L1 | 40 µH 6 A<br>10–15 turns on a ferrite core |
| T3, T4, T5 | TIC 106 or BT 136 |
| B1, B2, □3 | 60 watt incandescent lamp |
| □Mi□ | Low-impedance microphone |

**Electrical Project: Quiz Master (Option 2 of 6)**

This circuit may be used to indicate 'fastest finger first'. It has a globe for each contestant and one for the quiz master.

When a button is pressed the corresponding globe is illuminated. The quiz master globe is also illuminated and the cathode of the 9,1 V Zener diode sees approximately mid-rail voltage. The Zener diode comes out of conduction and no voltage appears across the 120 R resistor. No other globes can be lit until the circuit is reset.




| COMPONENT LIST | |
|---|---|
| R1, R2, R3 | 10 kΩ ¼ W |
| R4 | 120 Ω ¼ W |
| T1, T2, T3 | BT 151 SCR |
| LMP1, 2, 3, 4 | 6 volt lamp |
| S1, S2, S3, S4 | Push-to-make switch |
| D1 | 9 V Zener diode |
| 12 volt batte□y/supply | |

## Electronic Project: Automatic Battery Charger (Option 3 of 6)

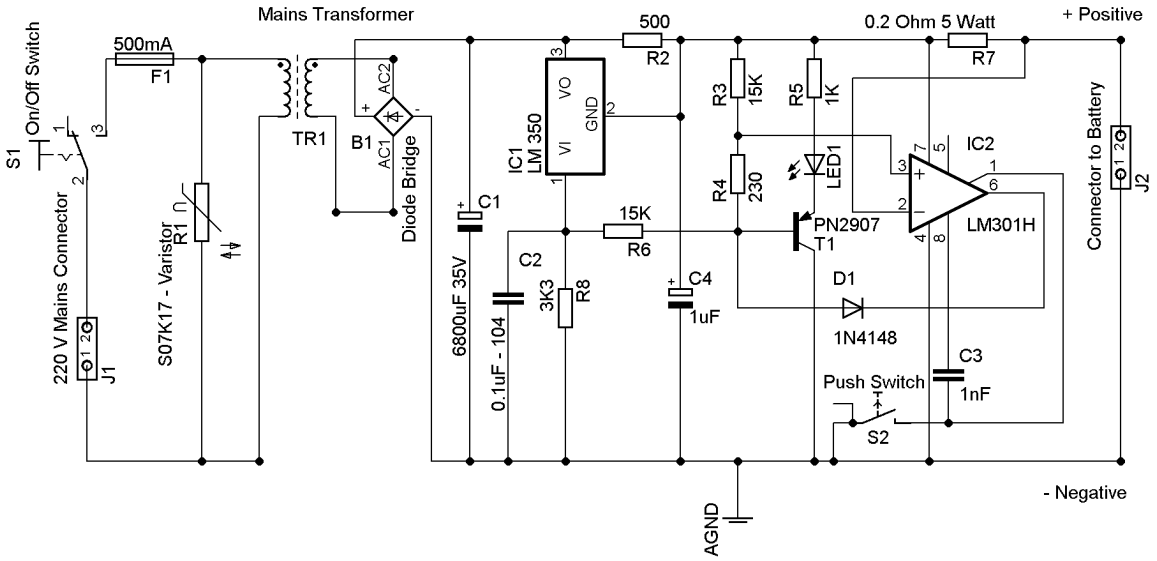
This automatic battery charger project is based on the National Semiconductor LM350 3 A adjustable regulator. It is designed to charge 12 V lead-acid batteries. When the switch SW1 is pushed the output of the charger will go up to 14,5 V. The initial charging current is limited to 2 A.

As the charge of the battery continues to rise, the charging current decreases to 150 mA and the output voltage is reduced to 12,5 V. At this stage the charging is terminated and the light-emitting diode lights up to indicate that the charging process has been completed.

The schematic diagram below shows how the various components are connected. The first part of the diagram shows how the DC power supply to LM350 is achieved. The combined use of varistor V1 and fuse F1 is to protect the circuit from overcurrent and power surge of the mains supply.

Transformer T1 is used to step down the input voltage from the mains to 16 V AC. Diode bridge DB and electrolytic capacitor E1 are used to rectify the AC voltage to DC voltage.

This rectified DC power supply is fed into the input of the second circuit where LM350 and operational amplifier LM301A are used to control the charging current and voltage of the lead-acid battery. Once the charge is full, transistor Q1 will turn ON and LED L1 will be ON to indicate that the charging has been completed. A heat sink is attached to LM350 to transfer the heat generated from the regulator to the ambient.




| COMPONENT LIST | |
|---|---|
| R1 | Varistor 14 mm |
| R2 | 500 ohm, 5 W |
| R3, R6 | 15 K ¼ W |
| R4 | 230 ohm ¼ W |
| R5 | 1 K |
| R7 | 0,2 ohm, 5 W |
| R8 | 3K3 ¼ W |
| J1 | Mains supply |
| J2 | 12 V connector for battery/battery clamps |
| F1 | 500 mA fast-blow fuse |
| TR1 | 240 V–16 V transformer 3 A (+/-50 VA) |

| COMPONENT LIST | |
|---|---|
| B1 | 5 A diode bridge |
| C1 | 6 800 uF 35 V electrolytic capacitor |
| C2 | 0,1 uF ceramic 104 |
| C3 | 1 nF ceramic 102 |
| C4 | 1 uF electrolytic 25 volt |
| D1 | 1N 4148 diode |
| IC1 | LM350 16 volt positive voltage regulator |
| IC2 | LM301 H operational amplifier |
| S1 | On/Off switch for mains voltage |
| S2 | Push-to-make switch |
| LED 1 | Red LED 5 mm |

**Electronic Project: Battery-voltage Bar-graph Display (Option 4 of 6)**

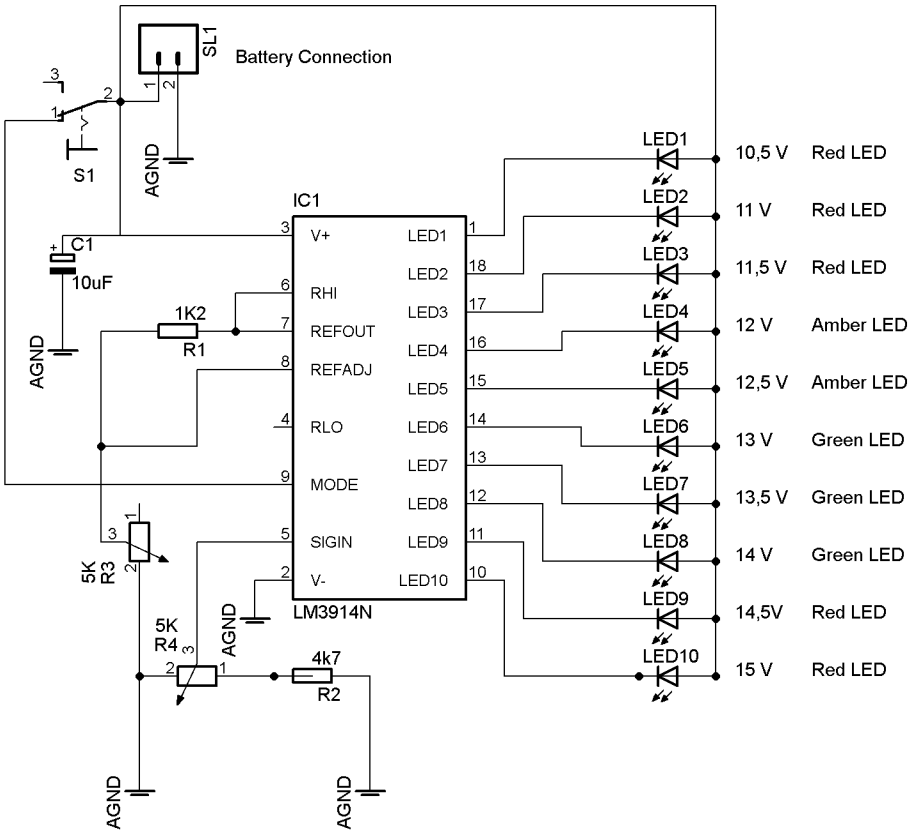
*(This project can be used in conjunction with the automatic battery charger or with any battery charger circuit.)*

This bar-graph LED-battery-level-indicator project is based on the LM3914 monolithic IC of the National Semiconductor that senses the voltage levels of the battery and drives the 10 light-emitting diodes based on the voltage level that is detected.

It provides a linear analogue display output and has a pin that can be configured to display the output in moving dot or bar graph. The current driving the LEDs is regulated and programmable, hence limiting resistors are not required.

The schematic diagram below shows how the various components are connected. Switch S1 is used to change the display type from moving dot to bar graph type. When S1 is ON the display type is bar graph, but when it is OFF the display changes to the moving-dot type.

R3 is used to set the lower limit of the display. Use a variable DC power supply and set the VBAT to 10,5 V. Adjust VR1 until the LED L1 turns ON. Next, set the VBAT to 15 V; adjust VR2 until all the LEDs turn ON (when S1 is ON).




| COMPONENT LIST | |
|---|---|
| R1 | 1K2 ¼ W 5% |
| R2 | 4K7 ¼ W 5% |
| R3 | 5 K potentiometer |
| LED 1–10 | LED – Red, Amber, Green |

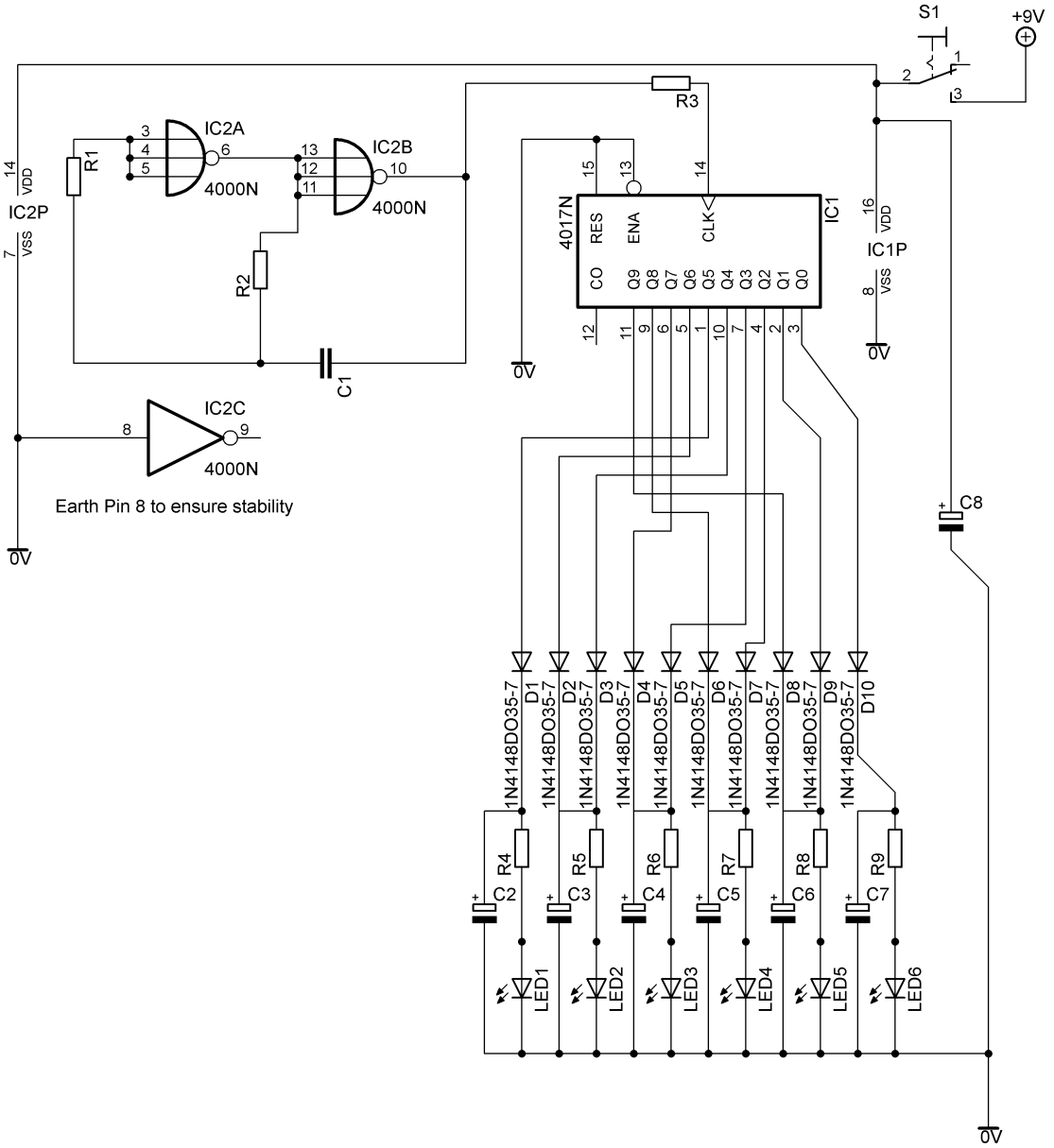
| COMPONENT LIST | |
|---|---|
| IC1 | LM3914 N bar-graph display driver |
| C1 | 10 µF 25 volt electrolytic capacitor |
| S1 | SPST toggle switch |

**Digital Project: Light Rider (Option 5 of 6)**

The circuit uses two NAND gates as an oscillator, feeding a clock pulse to the 4017 Johnson IC. The diodes assist in ensuring a forward and backward-flashing pattern.

The capacitors are added to allow for a smooth effect, just like the 1980's hit TV series, *Knight Rider*.



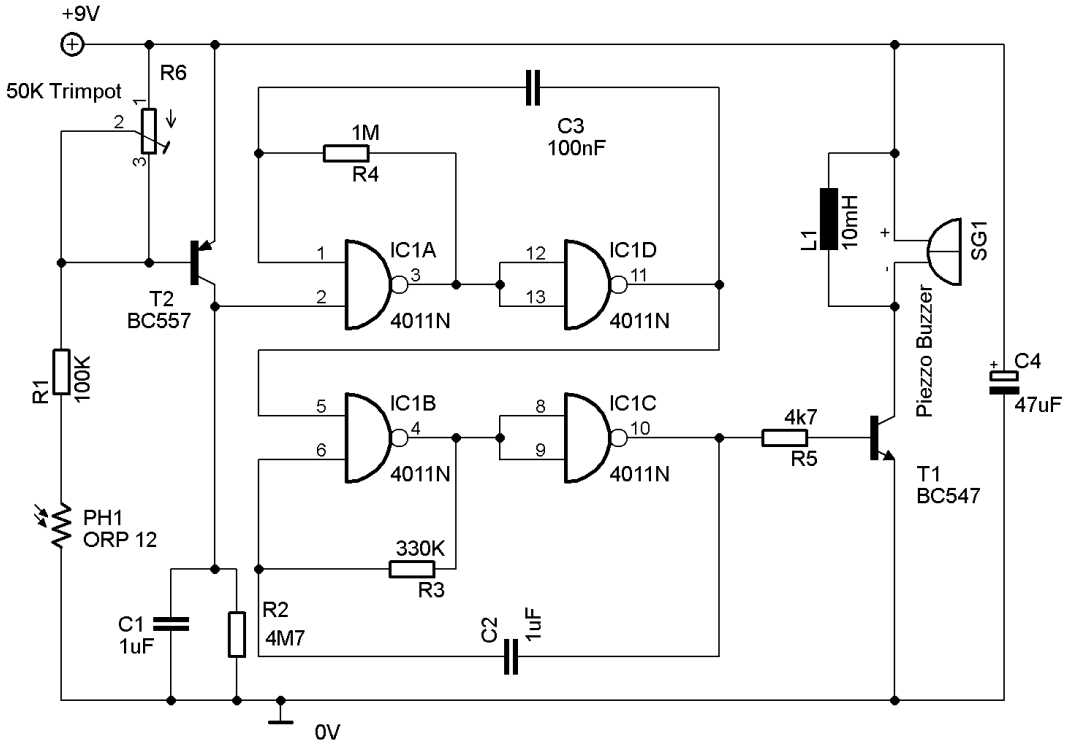

| COMPONENT LIST | |
|---|---|
| IC1 | CD 4017 Johnson decade counter/ divider IC |
| IC2 | CD4000 – dual 3-input NAND gate IC plus inverter |
| R1, R2 | 470 K ¼ W (2 off) |
| R3 | 47 K ¼ W |
| R4–R9 | 1 K ¼ W (6 off) |
| C1 | 100 nF polyester cap (104) |

| COMPONENT LIST | |
|---|---|
| C2–C8 | 100 µF 10 V (or more) radial electrolytic (7 off) |
| D1–D10 | 1N 4148 diode (10 off) |
| LED1–LED6 | 5 mm LED (colour of your choice) (6 off) |
| S1 | SPST toggle switch |
| PP3 battery clip | |
| 9 V PP3 battery | |

**Digital Project: Light Alarm (Option 6 of 6)**

The light alarm utilises a light-dependant resistor (LDR) that triggers the BC557 PNP transistor. The logic circuit shown is a monostable multivibrator which acts as a timer to switch on the driver transistor for the piezo buzzer.

When triggered the circuit should let out a loud buzzing sound for a predetermined time. You can alter the time period by experimenting with the values of the feedback resistors and the capacitors in the logic portion of the circuit diagram.




| COMPONENT LIST | |
|---|---|
| IC1 | 4011 quad 2-input NAND gate |
| R1 | 100 K ¼ W |
| R2 | 4M7 Ω ¼ W |
| R3 | 330 kΩ ¼ W |
| R4 | 1 MΩ ¼ W |
| R5 | 4k7 Ω ¼ W |
| R6 | 50 K trim pot |

| COMPONENT LIST | |
|---|---|
| C1, C2 | 1 µF Mylar capacitor |
| C1 | 100 nF polyester cap (104) |
| C3 | 100 nF polyester cap |
| C4 | 47 µF electrolytic 16 V rad cap |
| T1 | BC 547 NPN |
| T | BC 557 PNP |
| L1 | 10 mH inductor |
| PH 1 | ORP 12 LDR |
| SG 1 | 9–12 V piezo buzzer |
| PP3 battery clip | |
| 9 V PP3 battery | |

## 2.8 Working mark sheet

(A working Excel file is provided with this PAT.)

| PAT mark sheet | | Term 1 | | Term 2 | | Project | | | Total = 250 Term1 + Term 2 + Project | Mark out of 100 | Moderated Mark |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Name of Learner (Alphabetical) | Simulation 1 50 | Simulation 2 50 | Simulation 3 50 | Simulation 4 50 | Design and Make Part 1–80 | Design and Make Part 2–20 | Design and Make Total = 50 | | | |
| 0 | E.g. John Q Public | 45 | 10 | 30 | 25 | 30 | 10 | 20 | 135 | 54% | 54% |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
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| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| | **Total** | | | | | | | | | | |
| | **Average** | | | | | | | | | | |

Teacher: _____ Moderator: _____ Principal: : _____

Signature: _____ Signature: _____ Signature: _____

Date: _____

School Stamp

## 3. LEARNER GUIDELINES

**PAT 2017 Cover Page** (Place this page at the front of the PAT.)

# Department of Basic Education
# Grade 12 National Senior Certificate 2017
# Practical Assessment Task – Electrical Technology

Time Allowed: Term 1 to Term 3 (2017)

Learner Name: _____

Examination Number: _____

School: _____

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**Evidence of Moderation:**

**NOTE:** When the learner evidence (LE) selected has been moderated at school level, the table will contain evidence of moderation. Provincial moderators will sign the provincial moderation and only sign if re-moderation is needed.

| Moderation | Signature | Date | Signature | Date |
|---|---|---|---|---|
| School-based | | | | |
| Provincial moderation | | | Re-moderation | |

**Mark Allocation**

| PAT Component | Maximum mark | Learner mark | Moderated mark |
|---|---|---|---|
| Simulation 1 | 50 | | |
| Simulation 2 | 50 | | |
| Simulation 3 | 50 | | |
| Simulation 4 | 50 | | |
| Design and Make Project – Circuit (80/2) | 40 | | |
| Design and Make Project – Enclosure (20/2) | 10 | | |
| **Total** | **250** | | |

## 3.1 Instructions to the learner

- This PAT counts 25% of your final promotion mark.
- All work produced by you must be your own effort. Group work and co-operative work are not allowed.
- The PAT must be completed over three terms.
- The PAT must contain ANY 4 simulations and a practical project.
- Calculations should be clear and include units. Calculations should be rounded off to TWO decimals. SI units should be used.
- Circuit diagrams may be hand-drawn or drawn on CAD. NO photocopies or scanned files are allowed.
- Photographs are allowed and may be in colour or grey scale. Scanned photographs and photocopies are allowed.
- You are allowed/encouraged to use recycled components.
- This document must be placed inside your PAT file together with the other evidence.

## 3.2 Declaration of authenticity (COMPULSORY)

Declaration: I _____ (Name) herewith declare that the work represented in this evidence is entirely my own effort. I understand that if proven otherwise, my final results will be withheld.

_____ _____
Signature of learner Date

## 4. CONCLUSION

On completion of the practical assessment task learners should be able to demonstrate their understanding of the industry, enhance their knowledge, skills, values and reasoning abilities as well as establish connections to life outside the classroom and address real world challenges. The PAT furthermore develops learner's life skills and provides opportunities for learners to engage in their own learning.

**Design and Make Project**

Time: January to August 2017

Learner Name: _____

School: _____

Examination Number: _____

Title/Type of Project: _____

**Instructions**

- This section is COMPULSORY for all learners.
- The teacher will choose a circuit for the project.
- The checklist below must be used to ensure all the required tasks for the PAT have been completed.

**PAT Checklist**

| No. | Description | Tick (☑) | |
|---|---|---|---|
| | | No | Yes |
| | **Design and Make: Part 1** | | |
| 1 | Circuit diagram drawn | ☐ | ☐ |
| 2 | Circuit description completed | ☐ | ☐ |
| 3 | Component list completed | ☐ | ☐ |
| 4 | Tools list for circuitry populated | ☐ | ☐ |
| 5 | Measuring instrument list completed | ☐ | ☐ |
| 6 | Evidence of prototype printed and pasted into the file | ☐ | ☐ |
| 7 | Learner's own Vero-board/PCB planning/design printed and included in file | ☐ | ☐ |
| | **Design and Make: Part 2** | | |
| 1 | Enclosure design completed and included in the file | ☐ | ☐ |
| 2 | Unique name written down and included on the enclosure | ☐ | ☐ |
| 3 | Logo designed and included on the enclosure | ☐ | ☐ |
| | **Miscellaneous** | | |
| 1 | Enclosure included in the project | ☐ | ☐ |
| 2 | Enclosure prepared and drilled according to the design | ☐ | ☐ |
| 3 | Enclosure finished off and completed with name and logo | ☐ | ☐ |
| 4 | PCB securely mounted in the enclosure using acceptable techniques | ☐ | ☐ |
| 5 | Is circuit inside the enclosure accessible? | ☐ | ☐ |
| 6 | Internal wiring neat and ready for inspection | ☐ | ☐ |
| 7 | File and project completed and ready for moderation at the workshop/room | ☐ | ☐ |

## Design and Make: Part 1

1. **Circuit diagram**
   Draw a circuit diagram of your project.

2. **Project: Description of operation**

Use the space provided below to give an overview of how the project functions. Use your own words and do some research of your own.

3. **Component List**
Draw up a list of the components you will need from the circuit diagram.

| | Quantity | Description and value | Label on circuit diagram |
|---|---|---|---|
| E.g. | 10 | 1 K ¼ W carbon-film resistor | R1 |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |

4. **Tools List**
Draw up a list of tools you will need to complete the PAT circuitry. You may add to the list as you proceed through the PAT.

| | Description | Purpose/Use |
|---|---|---|
| E.g. | Long-nosed pliers | Used to bend wires and insert tips of stripped wire into board |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |

5. **Instruments List**
Draw up a list of instruments you will need to test your PAT. You will add to this list as you go along.

| | Description | Purpose/Use |
|---|---|---|
| E.g. | Ammeter | Placed in series with the circuit to indicate the current flowing |
| 1 | | |
| 2 | | |
| 3 | | |

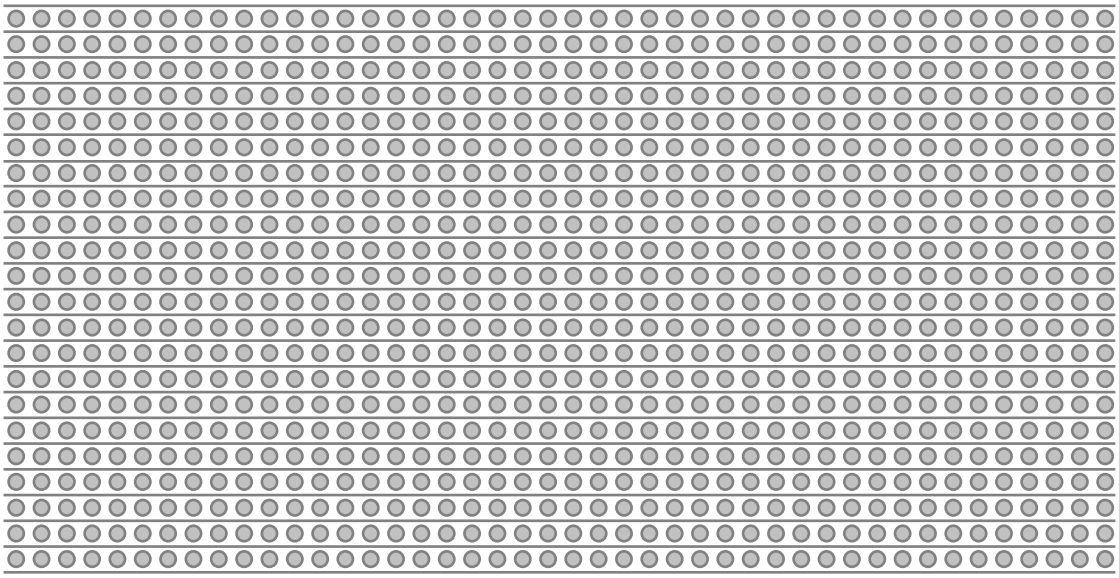
6. **Evidence of prototype**
Take photographs of the working prototype on the breadboard using a digital camera or a cellphone and attach after this page. If measurements were taken, insert evidence thereof as well. Use labels to describe what is done in each photograph.

7. **Vero-board planning OR PCB design**

If you do not use a Vero-board, add evidence of the PCB layout after this page.
Actual Vero-board hole spacing 0, 1' (2, 54 mm).
Use an **X** to show breaks made on the track

**Final Design – Vero-board**



**Printed Circuit Board Planning**

## ASSESSMENT OF THE DESIGN AND MAKE PHASE: PART 1

(Items not submitted will not be awarded a mark (0).)

| Task Description | Mark Allocation (Tick the appropriate level next to the task indicated) | | | | | |
|---|---|---|---|---|---|---|
| | **0 Not submitted** | **1 Not achieved** | **2 Not competent yet** | **3 Competent** | **4 Highly competent** | **5 Outstanding** |
| **Circuit diagram** | ☐ | ☐The learner was unable to draw a circuit diagram. | ☐The learner was able to partially draw a circuit diagram, but drew more than half the symbols incorrectly. | ☐The learner was able to draw the circuit diagram correctly and drew more than half the symbols incorrectly. | ☐The learner was able to draw the circuit diagram successfully and drew all the symbols correctly, but did not label all the parts. | ☐The learner was able to draw the circuit diagram successfully and drew the parts correctly. Everything was labelled according SI unit standards and the learner made special effort to ensure that the circuit diagram was neat. |
| **Circuit description** | ☐ | ☐The learner was unable to describe the circuit operation. | ☐The learner was able to partially explain how the circuit operates. | ☐The learner was able to describe the operation of the circuit diagram, but made mistakes on fewer than half the components. | ☐The learner was able to explain the operation of the circuit diagram successfully and identified all the symbols correctly. | ☐The learner was able to explain the operation of the circuit diagram successfully and identified the parts correctly. The learner was able to show evidence of how to alter the circuit to change its operating characteristics. |
| **Prototype circuit was working on the breadboard** | ☐Did not work **(0 marks)** | ☐Circuit was partly operational. No photographs of prototyping were included. **(3 marks)** | | ☐The circuit was fully operational, but the circuit in the photograph was similar to other learners' efforts. **(5 marks)** | ☐Circuit was fully operational. The photograph included did not resemble other learners' efforts, but no name was included. **(10 marks)** | ☐ Circuit was fully operational. The photograph included showed the circuit and name of the learner and it was unique. The photograph was clear and components were distinguishable. **(15 marks)** |
| **Trouble-shooting on the breadboard** | ☐ | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify one mistake. | ☐The circuit was complete and the learner was able to identify and rectify two mistakes. | ☐ The circuit was complete and the learner was able to identify and rectify all mistakes. If the learner's circuit worked first time, he/she was able to assist other learners with trouble-shooting. |

| Task Description | Mark Allocation (Tick the appropriate level next to the task indicated) | | | | | |
|---|---|---|---|---|---|---|
| | 0<br>Not submitted | 1<br>Not achieved | 2<br>Not competent yet | 3<br>Competent | 4<br>Highly competent | 5<br>Outstanding |
| **Vero-board/ Printed circuit board**<br><br>**Planning and layout stage only** | ☐Used a kit | ☐The learner was unable to plan the Vero-board/PCB layout using the circuit diagram supplied. | ☐The learner was able to plan correctly and placed 4 or fewer components on the Vero-board/ PCB design correctly. | ☐The learner was able to plan correctly and place more than 4, but fewer than **8** components correctly on the Vero-board/PCB design. The learner copied the kit PCB with the help of the teacher. | ☐The learner was able to plan successfully and place all the components correctly on the Vero-board/PCB design with links. The learner designed a new PCB layout with the help of the teacher. | ☐The learner was able to plan successfully and place all the components correctly on the PCB taking into consideration space used, alignment of components and component types. The learner designed the new PCB layout without the help of the teacher. |
| **Component selection and identification** | ☐ | ☐The learner was unable to identify and select any components. | ☐The learner was able to identify and select fewer than 4 components. | ☐The learner was able to select more than 4, but fewer than 8 components. | ☐The learner was able to identify and select all components. | ☐The learner identified and selected components quickly and without the help of the teacher. The learner was also able to identify equivalent values using a variety of methods. |
| **Instrument selection and use** | ☐ | ☐The learner was unable to identify and select any instruments. | ☐The learner identified and selected the wrong instruments. | ☐The learner was able to select the correct instruments, but used them incorrectly/unsafely. | ☐The learner was able to identify and select all instruments correctly and used them correctly. | ☐The learner identified and selected instruments quickly and without the help of the teacher. The learner was also able to use instruments correctly in a safe ergonomic manner. |
| **PCB manufacturing (Development and etching)** | ☐ | ☐The learner was unable to make a PCB/ used a kit.<br>OR<br>The learner used a Vero-board, but it did not work.<br>**(1 mark)** | ☐The learner over-/under-developed the board (over-/under exposed to UV light). **(2 marks)** | ☐The learner overetched/ underetched the PCB. Holes drilled pierced/broke the tracks & it was not finished/ sanded down neatly.<br>OR<br>The learner used a Vero-board, but it was only partially operational.<br>**(5 marks)** | ☐The learner was able develop and etch the board neatly. All holes drilled were finished/sanded down neatly. There was no evidence of tinning.<br>OR<br>The learner used a Vero-board and the circuit operated correctly.<br>**(10 marks)** | ☐The learner was able to develop and etch the board neatly. All holes drilled were finished/ sanded down neatly. The learner tinned all tracks and the board is exceptionally neat.<br>**(15 marks)** |

| Task Description | Mark Allocation (Tick the appropriate level next to the task indicated) | | | | | |
|---|---|---|---|---|---|---|
| | 0<br>Not submitted | 1<br>Not achieved | 2<br>Not competent yet | 3<br>Competent | 4<br>Highly competent | 5<br>Outstanding |
| **Solder technique** | ☐ | ☐Solder work was not neat, contained dry and loose joints. **(2 marks)** | ☐Solder work contained more than 5, but fewer than 10 dry or loose joints. **(4 marks)** | ☐Solder work contained fewer than 5 dry or loose joints. **(6 marks)** | ☐Solder work was neat, and there was no evidence of dry joints or loose connections. **(8 marks)** | ☐Solder work was exceptionally neat and smooth. The learner sealed the solder side against corrosion, using clear lacquer. (Plastic 70/ Polyurethane etc.) **(10 marks)** |
| **Component placement – neatness and aesthetics** | ☐ | ☐Components were placed erratically and it appeared untidy. | | ☐Most components were placed tidily. Fewer than 5 components appeared untidy. | ☐All components were placed well. The board appeared tidy and neat. | ☐Components were aligned exceptionally well. Component displacement from the board surface had been considered. All colour codes of resistors were aligned. Capacitors and other components were aligned and appeared neat. |
| **Housekeeping** | ☐ | ☐The learner did no housekeeping. | ☐The learner did housekeeping under duress. | ☐The learner did housekeeping under the supervision of the teacher. | ☐The learner did housekeeping after she/he was reminded by the teacher. | ☐The learner was able to do housekeeping without supervision or being reminded by the teacher. Housekeeping was done excellently. |
| | | | | | **Rubric (Maximum of 80)** | |

## Design and Make: Part 2

1. **Enclosure design**
   Design an enclosure and include the layout of the PCB and parts in the enclosure. Use colour to accentuate your design. You are allowed to use hand-drawn designs and also the CAD programme.

Show the top, front and side views below.

2. Manufacture/Obtain an enclosure according to your design.

3. Choose a name for your device. Write down the name of the device below.

_____

4. Design a logo for your device below.

## ASSESSMENT OF THE DESIGN AND MAKE PHASE: PART 2

Items not submitted will be awarded a zero (0).

| Task Description | Mark Allocation (Tick the appropriate level next to the task indicated) | | | | | |
|---|---|---|---|---|---|---|
| | 0<br>Not submitted | 1<br>Not achieved | 2<br>Not competent yet | 3<br>Competent | 4<br>Highly competent | 5<br>Outstanding |
| **Enclosure design, planning and layout** | ☐ | ☐The learner attempted a design but was unable to plan the enclosure layout. | ☐The learner designed an enclosure using freehand sketches only.<br>OR<br>The learner was able to plan correctly and place fewer than 2 items according to the initial design. | ☐The learner designed an enclosure using freehand concept sketches and then used an EGD approach for the final drawing with dimensions. No colour was used.<br>OR<br>The learner was able to plan correctly and place more than 2, but fewer than 4 parts correctly according to the planned design. | ☐The learner designed an enclosure using an EGD approach for the final drawing with dimensions. Colour was used in concept sketches and models.<br>OR<br>The learner was able to plan successfully and place all the components correctly in the enclosure, as planned in the design. | ☐The final design was in an EGD drawing and on CAD in colour with labels and dimensions. Colour was used in concept sketches and models.<br>OR<br>The learner was able to plan successfully and place all the parts correctly in the enclosure taking into consideration space used, alignment of components and component types and wire wrapping. |
| **Name and logo design** | ☐ | ☐The name and logo design were on paper only, not on the enclosure. | ☐The learner applied a name or a logo, but the appearance was not neat. | ☐The learner applied the name and logo of the device neatly, but used an existing logo from a company. | ☐The learner applied the name and logo of the device neatly. The name and logo design were original. | ☐The learner applied the logo and name neatly on different places on the project. The learner also included a specification plate/list. |
| **Safety** | ☐ | ☐The learner did not work safely. | ☐The learner worked safely after being reprimanded. | ☐The learner worked safely under supervision of the teacher. | ☐The learner worked safely without being reminded by the teacher. | ☐The learner was able to work safely without supervision or being reminded by the teacher. Safety was excellent. |
| **Final product** | ☐ | ☐The learner did not produce a finished product. | ☐Finished product gave a poor overall impression and did not work. | ☐The learner produced a final product that looked acceptable, but did not work. | ☐The learner produced a product that looked acceptable and it worked. | ☐The learner was able to finish the product and exhibited exceptional levels of competence in numerous areas. The project looked outstanding and worked very well. |
| | | | | | **Rubric (Maximum of 20)** | |

**Electrical – 1**

Simulation 1 Time: 1 hour

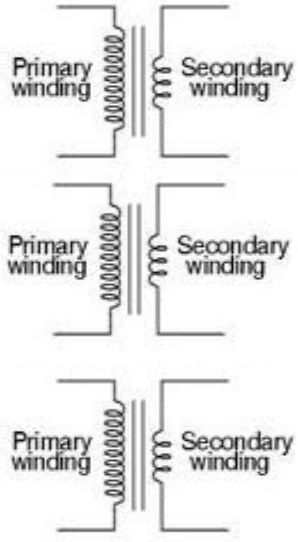
Learner Name: _____

School: _____

Examination Number: _____

**Connecting three single-phase transformers to a three-phase supply**

1. **Purpose:**
   - To connect three identical single-phase step-down transformers in star-delta to a three-phase supply
   - Connect the secondary to a load that consists of three identical incandescent lamps that are connected in delta
   - Measure the primary and secondary line and phase voltages and currents




2. **Procedure:**
   - Draw the circuit diagram in which the transformers are connected in a star/delta connection.
   - Connect three identical single-phase step-down transformers in star-delta to a three-phase supply.
   - Connect the secondary to a load that consists of three identical incandescent lamps that are connected in delta.
   - Measure the primary and secondary line and phase voltages and currents.

3. **Equipment:**
   - Three identical step-down single-phase transformers
   - A three-phase supply
   - Multimeter
   - Connecting wires
   - Three lamp holders
   - Three identical incandescent lamps

   **NOTE:**
   - The secondary voltage of the transformer is not critical. The only requirement is that the secondary voltage and the voltage of the lamps are compatible.
   - It is IMPORTANT that the three transformers are IDENTICAL with respect to impedance and transformation ratios.
   - It is the duty of the teacher to verify that the learners are connecting the transformers correctly, before connecting the mains supply. If you are not entirely sure of your connections do not switch on. Test for short circuits.
   - Mains supply can be lethal. Be extremely careful.
   - Schools using older panels that are closed up and schools with no clamp meters should measure the primary line and phase voltages only.

4. **Results:**

   4.1 Draw the configuration of the transformers connected in star-delta using the correct colour coding. (17)
   Mark allocation: Primary connection (5) Secondary connection (6) Load (6)

   4.2 Correct practical connection including correct use of multimeter. (8)
   Mark allocation; subtract one mark for each mistake.

   4.3 Complete the table below by measuring the primary and secondary voltages and currents.

| PRIMARY | | | SECONDARY | | |
|---|---|---|---|---|---|
| $V_{L1}$= | $V_{PH1}$= | $I_{PH1}$=$I_{L1}$= | $V_{L1}$=$V_{PH1}$= | $I_{PH1}$= | $I_{L1}$= |
| $V_{L2}$= | $V_{PH2}$= | $I_{PH2}$=$I_{L2}$= | $V_{L2}$=$V_{PH2}$= | $I_{PH2}$= | $I_{L2}$= |
| $V_{L3}$= | $V_{PH3}$= | $I_{PH3}$=$I_{L3}$= | $V_{L3}$=$V_{PH3}$= | $I_{PH3}$= | $I_{L3}$= |

(18)

5. State the relationship between the following:

5.1 Line and phase voltage in a star-connected system

| |
|---|
| |
| |

(1)

5.2 Line and phase voltage in a delta-connected system

| |
|---|
| |
| |

(1)

5.3 Line and phase current in a star-connected system

| |
|---|
| |
| |

(1)

5.4 Line and phase current in a delta-connected system

| |
|---|
| |
| |

(1)

6. State three safety precautions when doing the connections and measurements.

| |
|---|
| |
| |
| |
| |

(3)

**TOTAL: 50**

**Electrical – 2**

Simulation 2 Time: 1 hour

Learner Name: _____

School: _____

Examination Number: _____

**Inspecting and testing the AC motor**

1. **Purpose:**
   - To conduct electrical and mechanical inspections of an AC motor using the checklist and report shown below
   - To test an AC motor using the checklist and report shown below

2. **Procedure:**
   - Use the list below to conduct an inspection and tests on an AC electrical motor.
   - Complete the results in the table below.

3. **Equipment:**
   - Three-phase AC motor
   - Multimeter
   - Insulation tester (Megger)

4. **Results:**
   Details of the motor being tested:

   Phase: _____ Supply voltage: _____

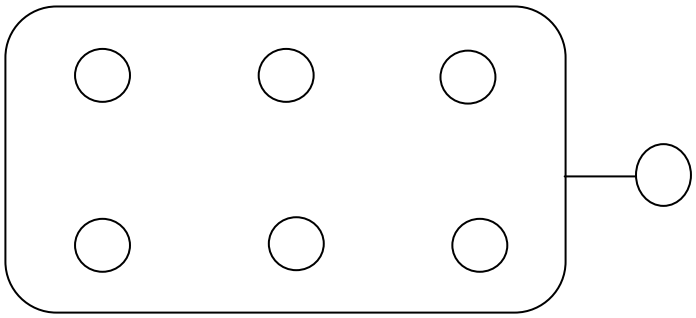
   Pole pairs: _____ Speed: _____

   Efficiency: _____ Current: _____

| DESCRIPTION | VISUAL INSPECTION AND READINGS TAKEN (Megger) | MARKS ALLOCATED |
|---|---|---|
| **Condition of windings: Measurements taken** | | |
| **Test 1: Continuity of the windings (3 marks)** | | |
| A1 – A2 | | |
| B1 – B2 | | |
| C1 – C2 | | |
| **Test 2: Insulation resistance between windings (3 marks)** | | |
| A1 – B1 | | |
| A1 – C1 | | |
| B1 – C1 | | |
| **Test 3 – Insulation resistance to earth (3 marks)** | | |
| A1 – Earth | | |
| B1 – Earth | | |
| C1 – Earth | | |
| **Test 4 – Mechanical inspection Note all errors (9 marks)** | | |
| **Condition of rotor and shaft** | | |
| Key/Key way | | |
| Front bearing | | |
| Back bearing | | |
| **Condition of motor frame** | | |
| Condition of termination box | | |
| Flange/Foot mount | | |
| Front/Back-end shield | | |
| Stator/Field housing | | |
| Mounting bolts and nuts/screws | | |
| Condition of cooling fan, fan cover and cooling fins | | |

Draw and label the correct connection of internal wiring on the drawing provided below: (3=coils) (4=labels)



(7)

| Test | Finding (4 marks) |
|---|---|
| Is motor operational? | |
| Earth resistance | |
| Insulation resistance | |
| Winding resistance | |

(4)

List the recommended repairs that should be done on the electrical motor being tested before it is energised.

_____

_____ (1)

**TOTAL: 30**

## RUBRIC SIMULATION 2: TESTING AN ELECTRIC MOTOR

| Task Description | Mark Allocation (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | **1 Not Achieved** | **2 Not competent yet** | **3 Competent** | **4 Highly competent** | **5 Outstanding** |
| **Inspection points** | ☐The learner did not identify any testing points. | ☐The learner was unable to identify more than 2 testing points. | ☐The learner was able to identify more than 2 testing points but could not motivate why these were used. | ☐The learner was able to identify testing points on and inside the motor. The learner was also able to motivate why these points had to be tested. | ☐The learner was able to indicate all testing points in and on the motor successfully. The learner was also able to motivate why these points should be tested and could list symptoms that indicated certain errors. |
| **Test continuity** | ☐The learner was unable to test continuity | | ☐The learner was able to test continuity, but did not know why this was done. | ☐The learner was able to test continuity correctly and had a basic idea of the reason for this. | ☐The learner was able to test continuity correctly and had a solid knowledge of the meters and the reasons for using them. |
| **Test earth resistance** | ☐The learner was unable to test earth resistance. | . | ☐The learner was able to test earth resistance, but did not know why this was done. | ☐The learner was able to test earth resistance correctly and had a basic idea of the reason for this. | ☐The learner was able to earth resistance correctly and had a solid knowledge of the meters and the reasons for using them. |
| **House-keeping** | ☐The learner did no house-keeping. | ☐The learner did house-keeping under duress. | ☐The learner did house-keeping under the super-vision of the teacher | ☐The learner did house-keeping after she/he was reminded by the teacher. | ☐The learner was able to do house-keeping without supervision or being reminded by the teacher. House-keeping was done excellently. |
| | | | | **Total of the Rubric (Maximum of 20)** | |
| | | | | **Written Task (Maximum of 30)** | |
| | | | | **Total (Maximum of 50)** | |

**Electrical – 3**

Simulation 3 Time: 3 hours

Learner Name: _____

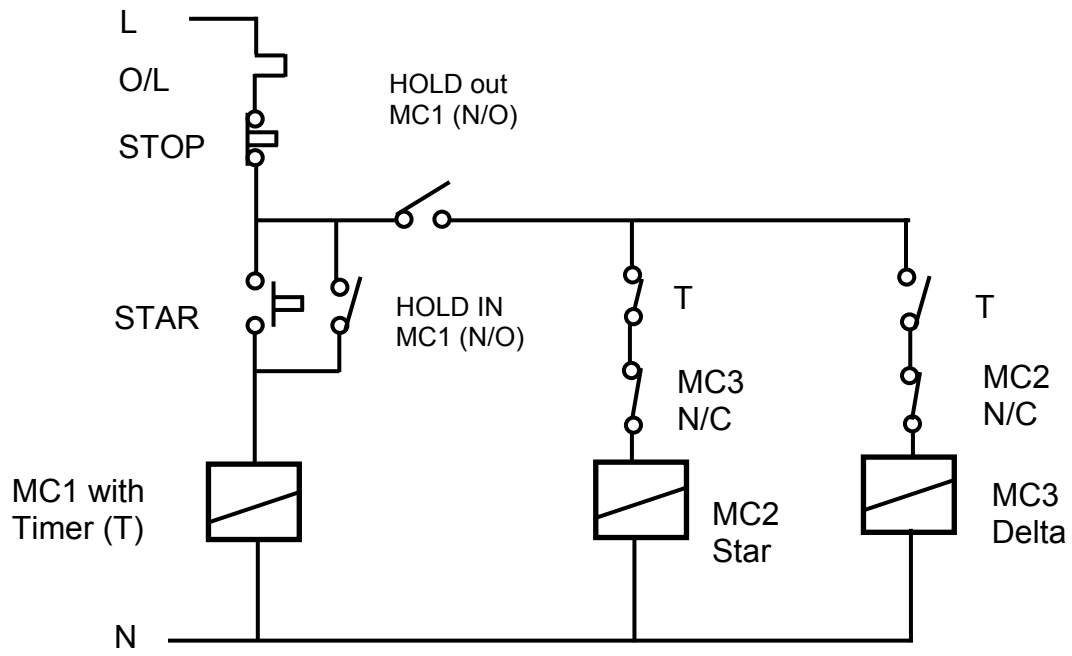
School: _____

Examination Number: _____

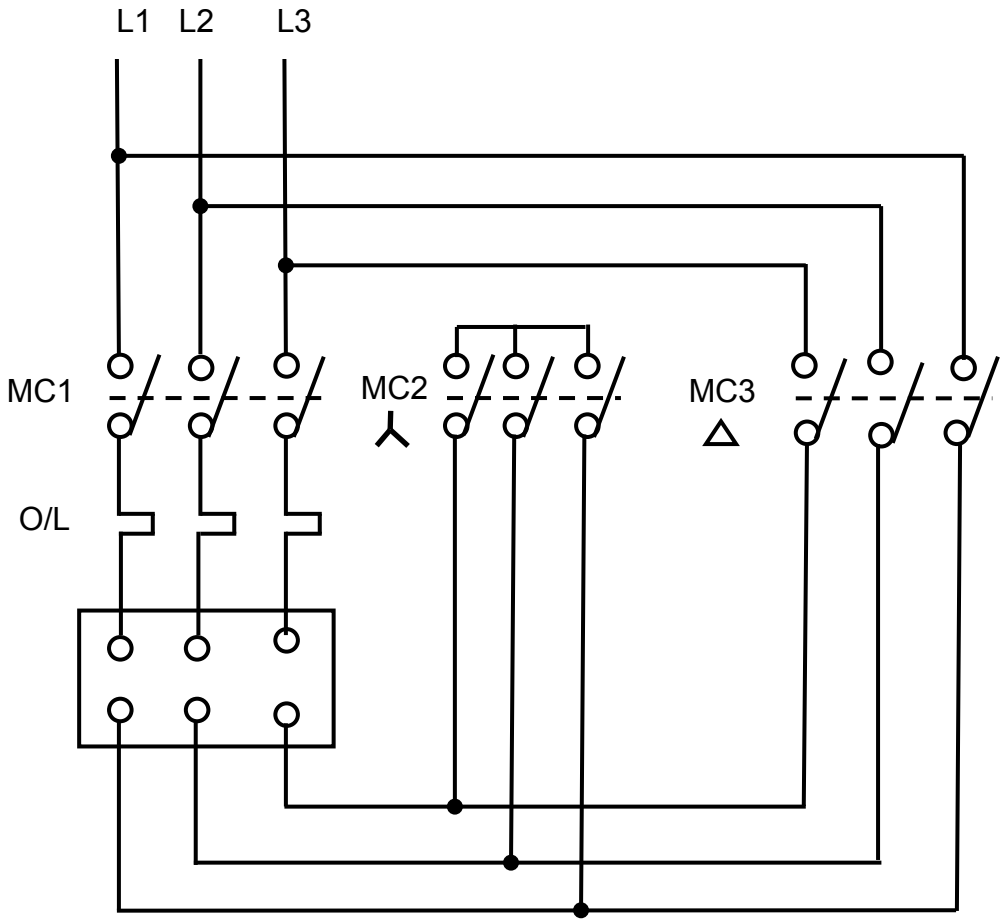
**Three-phase star-delta starter**

1. **Purpose:**
Practical simulation of a three-phase star-delta starter

**Control circuit**



**Power circuit**




**NOTE:** Teachers may use alternative circuits.

2. **Procedure:**
   - Connect the control circuit of a starter.
   - Check the correct operation of the control circuit with the assistance of the teacher.
   - Disconnect the control circuit from the power.
   - Connect the power circuit to the starter.
   - Check the correct connection of the power circuit with the assistance of the teacher.
   - Set overloads to correct settings.
   - Connect both power and control circuits for correct operation.

3. **Equipment:**
   - Two three-phase contactors with auxiliary contacts
   - One three-phase contactor with a timer
   - One three-phase overload relay
   - One stop button (press-button type)
   - One start button (press-button)
   - One three-phase circuit-breaker
   - One fuse for the control circuit
   - One three-phase squirrel-cage motor
   - Correct wire size or plug-in leads
   - Multimeter or continuity tester
   - Power supply – three phase

4. **Results:**
   - Measure the voltage across each phase when starting in star.
   - Measure the voltage across each phase when running in delta.

| STAR | DELTA |
|---|---|
| $V_{ph}$= | $V_{ph}$= |

(2)

5. **Questions:**

5.1 Describe why a star delta is used.

| |
|---|
| |
| |
| |
| |
| |

(4)

5.2 Describe how the starter functions.

| |
|---|
| |
| |
| |
| |
| |

(4)

**SUBTOTAL: 10**

## RUBRIC SIMULATION 3: THREE-PHASE-STAR-DELTA-STARTER

| **Task Description** | **Mark Allocation** (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | **0 Not achieved** | **1 Not competent yet** | **2 Competent** | **4 Highly competent** | **5 Outstanding** |
| **Identification and purpose of parts** | ☐The learner was unable to identify any parts. | ☐The learner was able to identify fewer than 3 parts. | ☐The learner was able to identify all parts, but did not know the functions thereof. | ☐The learner was able to identify all parts successfully and knew the purpose of most of the parts. | ☐The learner was able to identify all parts successfully and knew the purpose of all the parts. |
| **Control circuit wiring** | ☐The learner was unable to wire the control circuit. | ☐The learner was able to wire part of the control circuit. | ☐The learner was able to wire the control circuit, but could not establish retention at start. | ☐The learner was able to wire the control circuit successfully. | ☐The learner was able to wire the control circuit successfully. The learner followed a step-by-step approach, testing along the way and included pilot lights. |
| **Trouble-shooting: Control circuit** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but was not functional. The learner was unable to identify the problem. | ☐The circuit was complete, but not functional and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. The circuit was functional. | ☐The circuit was complete and the learner was able to identify and rectify all mistakes. |
| **Control circuit working** | ☐The circuit did not work. | | | | ☐The circuit worked. This must correlate with the circuit wiring marks. |
| **Main circuit wiring** | ☐The learner was unable to wire the main circuit. | ☐The learner was able to wire the main circuit partly correct, but did not use overload protection. | ☐The learner was able to wire the main circuit including overload protection, but did not know why it was used. | ☐The learner was able to wire the main circuit and test the overload protection and had a working knowledge of the circuit. | ☐The learner was able to test the main circuit correctly after assembly and had a well-founded knowledge of all the working parts. The learner was able to quickly re-assemble the circuit accurately without the aid of the circuit diagram. |
| **Trouble-shooting: Main circuit** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but was not functional. The learner was unable to identify the problem. | ☐The circuit was complete, but not functional and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. The circuit was functional. | ☐The circuit was complete and the learner was able to identify and rectify all mistakes. |
| **Main circuit working** | ☐The circuit did not work. | | | | ☐The circuit worked. This must correlate with the main circuit wiring marks. |
| **Safety** | ☐The learner did not work safely. | ☐The learner worked safely after being reprimanded. | ☐The learner worked safely under supervision of the teacher. | ☐The learner worked safely without being reminded by the teacher. | ☐The learner was able to work safely without supervision or being reminded by the teacher. Safety was excellent. |
| | | | | **Total of the Rubric (40) Maximum (50)** | |

**Electrical – 4**

Simulation 4 Time: 3 hours

Learner Name: _____

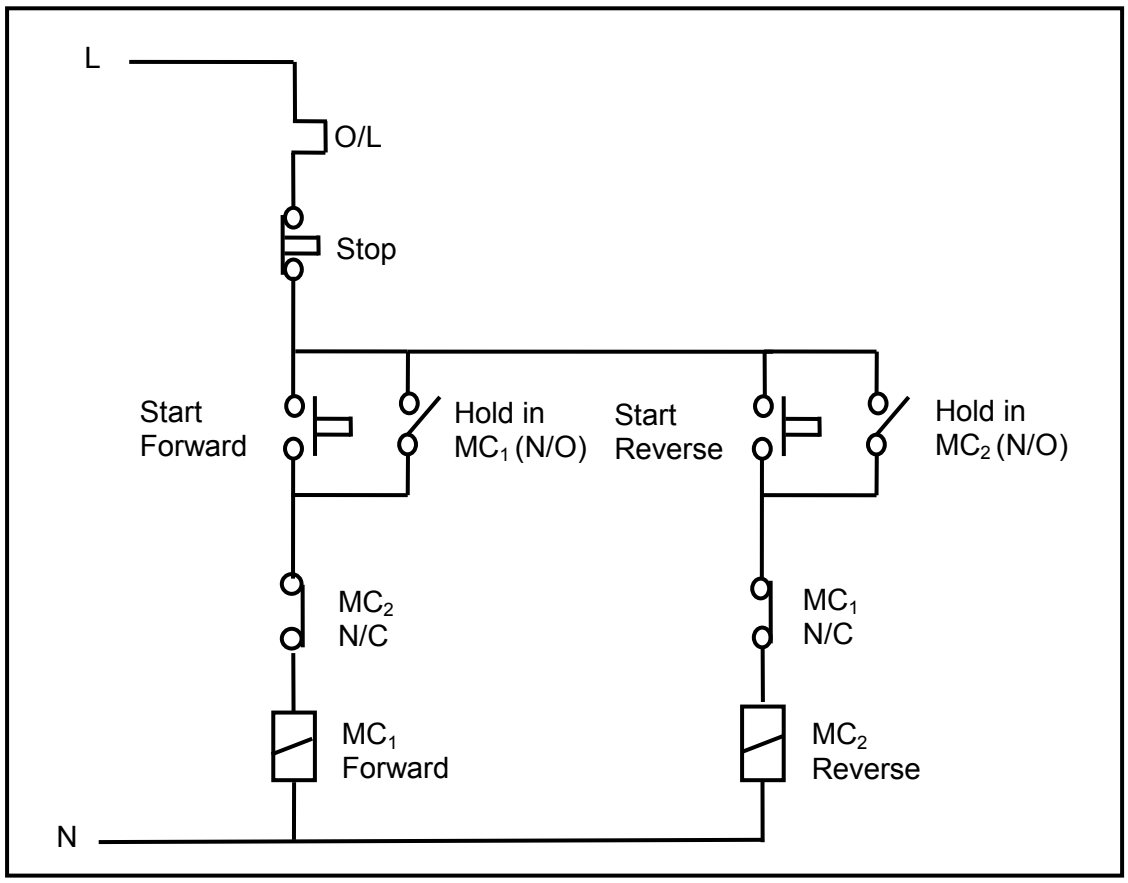
School: _____

Examination Number: _____

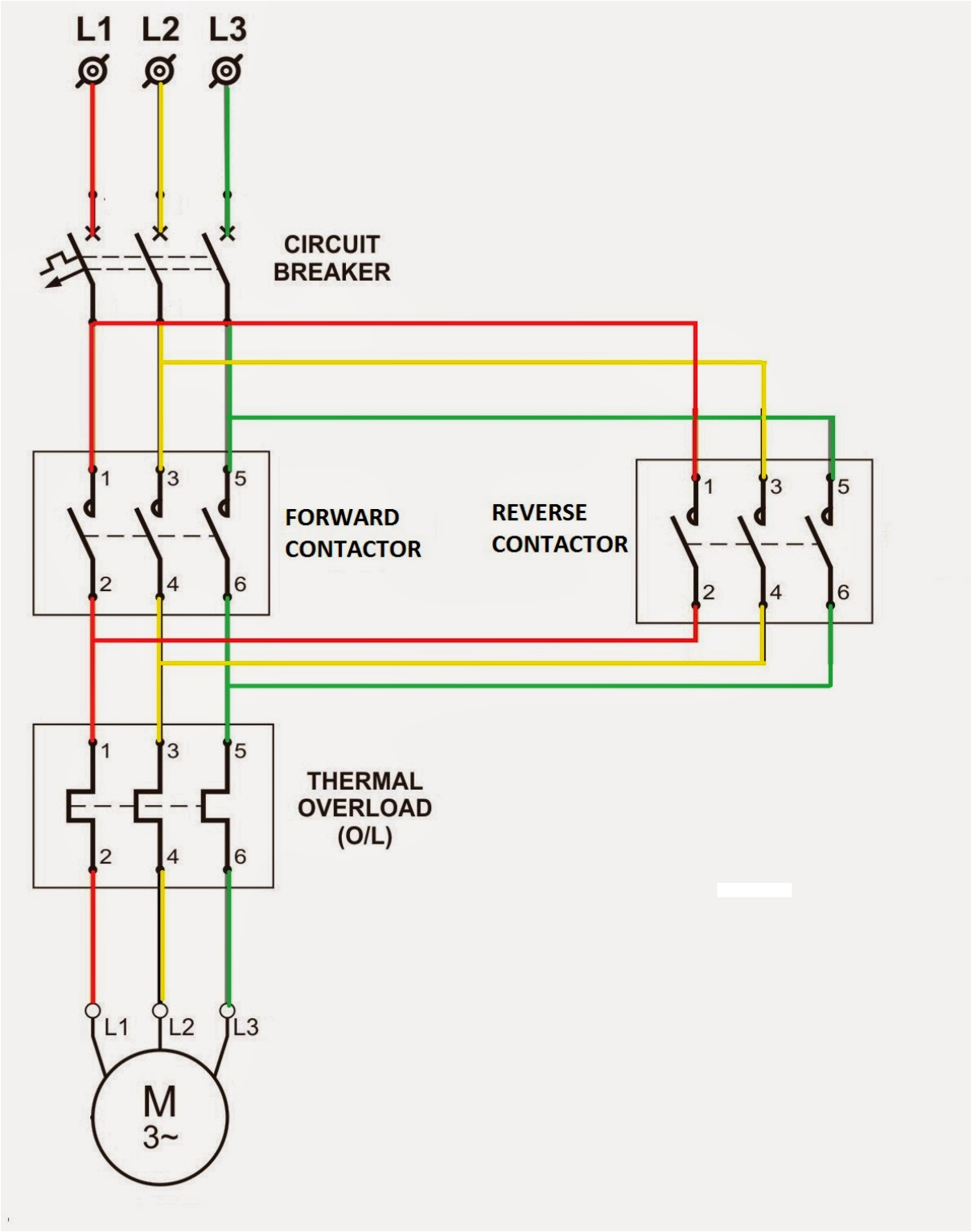
**Three-phase forward-reverse starter**

1. **Purpose:**
Practical simulation of a three-phase forward-reverse starter

Control circuit



Power Circuit




**NOTE:** Teachers may use alternative circuits.

2. **Procedure:**
   - Connect the control circuit of the starter.
   - Check the correct operation of the control circuit with the assistance of the teacher.
   - Disconnect the control circuit from the power.
   - Connect the power circuit of the starter.
   - Check the correct connection of the power circuit with the assistance of the teacher.
   - Set overloads to correct settings (Match the motor with the O/L).
   - Connect both power and control circuits for correct operation and start the motor in both directions.

3. **Equipment:**
   - Two three-phase contactors with auxiliary contacts
   - One three-phase overload relay
     OR
     One forward-reverse starter
   - One three-phase circuit breaker
   - One three-phase squirrel-cage motor
   - Correct wire size or plug-in leads
   - Multimeter or continuity tester
   - Power supply – three phase

4. **Questions:**

4.1 Describe the function of the starter.

(2)

4.2 Describe how the starter achieves its function.

(2)

4.3 Describe ONE practical application of this type of starter.

(2)

4.4 Describe why the motor cannot be switched into reverse when running in forward.

(4)

**SUBTOTAL: 10**

## RUBRIC SIMULATION 4: FORWARD-REVERSE MOTOR STARTER

| **Task Description** | **Mark Allocation** (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | **1 Not achieved** | **2 Not competent yet** | **3 Competent** | **4 Highly competent** | **5 Outstanding** |
| **Identification and purpose of parts** | ☐The learner was unable to identify any parts. | ☐The learner was able to identify fewer than three parts. | ☐The learner was able to identify all parts, but did not know the function thereof. | ☐The learner was able to identify all parts successfully and knew the purpose of most of the parts. | ☐The learner was able to identify all parts successfully and knew the purpose of all the parts. |
| **Control circuit wiring** | ☐The learner was unable to wire the control circuit. | ☐The learner was able to wire only the forward part of the circuit. | ☐The learner was able to wire both the forward and the reverse, but did not use interlocking. | ☐The learner was able to wire the control circuit for the forward and reverse successfully using interlocking. | ☐The learner was able to wire the control circuit for the forward and reverse successfully using interlocking. The learner followed a step by step approach, testing along the way and included pilot lights. |
| **Control circuit working** | ☐ The circuit did not work. | | | | ☐The circuit worked. This must correlate with the circuit wiring marks. |
| **Troubleshooting: Control circuit** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. | ☐The circuit was complete and the learner was able to identify and rectify all mistakes. |
| **Main circuit wiring** | ☐The learner was unable to wire the main circuit. | ☐The learner was able to wire the main circuit partly correct, but did not use overload protection. | ☐The learner was able to wire the main circuit, including overload protection, but did not know why it was used. | ☐The learner was able to wire the main circuit and test the overload protection and had a working knowledge of the circuit. | ☐The learner was able to test the main circuit after assembly correctly and had a well-founded knowledge of all the working parts. The learner was able to re-assemble the circuit quickly and accurately without the aid of the circuit diagram. |
| **Main circuit working** | ☐The circuit did not work. | | | | ☐The circuit worked. This must correlate with the main circuit wiring marks. |
| **Troubleshooting: Main circuit** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. | ☐The circuit was complete and the learner was able to identify and rectify all the mistakes. |
| **Safety** | ☐The learner did not work safely. | ☐The learner worked safely after being reprimanded. | ☐The learner worked safely under supervision of the teacher | ☐The learner worked safely without being reminded by the teacher. | ☐The learner was able to do work safely without supervision or being reminded by the teacher. Safety was excellent. |
| | | | | **Total of the Rubric (Maximum of 50)** | |

**Electrical – 5**

Simulation 5 Time: 3 hours

Learner Name: _____

School: _____

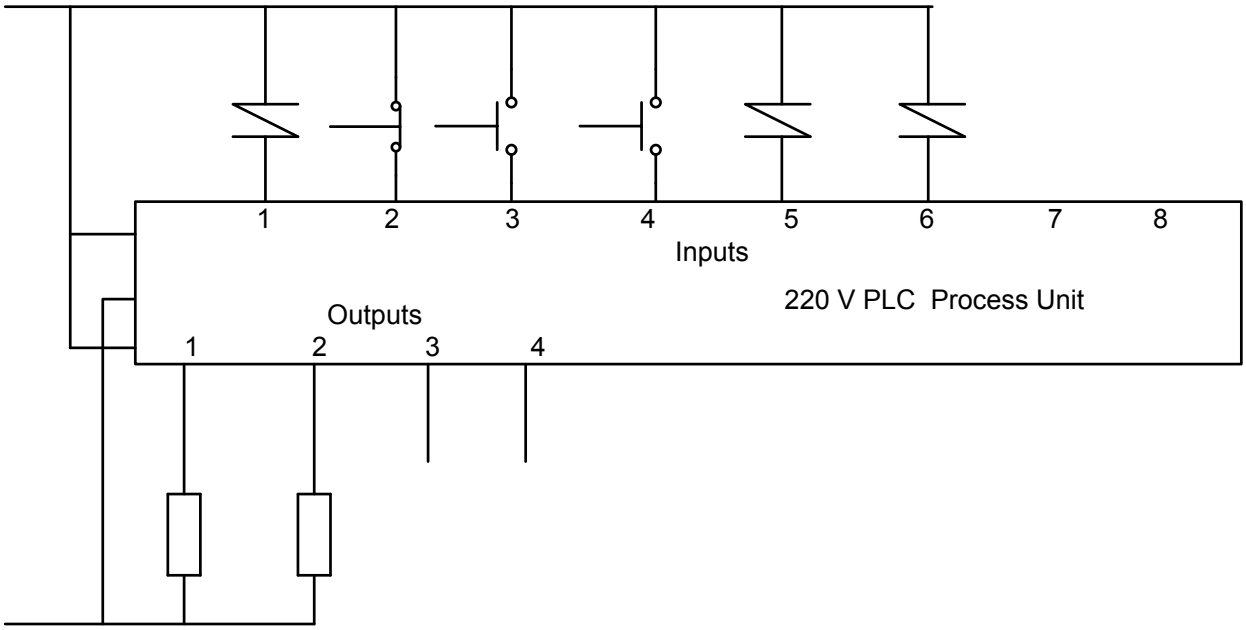
Examination Number: _____

**Three-phase forward-reverse starter using PLC**

1. **Purpose:**
   To connect a three-phase forward-reverse starter using PLC.

Control circuit and power circuit; see simulation 4 on pages 42 and 43.

Possible PLC practical connection.




| INPUTS | OUTPUTS |
|---|---|
| 1 O/L M | 1 $MC_1$ |
| 2 STOP $M_1$ | 2 $MC_2$ |
| 3 START FORWARD | |
| 4 START REVERSE | |
| 5 $MC_1$ N/C | |
| 6 $MC_2$ N/C | |

**NOTE:** Teachers may use alternative circuits.

2. **Equipment:**
   - Two three-phase contactors with auxiliary contacts
   - One three-phase overload relay
   - One three-phase circuit-breaker
   - Three-phase squirrel-cage induction motor
   - Correct wire size or plug in leads
   - Multimeter or continuity tester
   - Power supply – three phase
   - Desktop personal computer/Notebook/Laptop
   - PLC unit

3. **Procedure:**
   - Convert the control circuit of a three-phase forward reverse starter into a ladder logic diagram.
   - Write a simple ladder logic program.
   - Download the program to the PLC and run the program.
   - Wire the main circuit to the PLC unit.
   - Connect the motor to the main circuit.
   - Do not switch on the supply before the teacher has checked the circuit.
   - When the circuits are correct switch the supply on.
   - Run the PLC program to start the motor.

**TOTAL FROM RUBRIC: 50**

## RUBRIC SIMULATION 5: THREE-PHASE FORWARD REVERSE STARTER USING PLC

| Task Description | Mark Allocation (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | 0<br>Not achieved | 1<br>Not competent yet | 2<br>Competent | 4<br>Highly competent | 5<br>Outstanding |
| **Identification and purpose of parts** | ☐The learner was unable to identify any parts. | ☐The learner was able to identify fewer than 3 parts. | ☐The learner was able to identify all parts, but did not know the functions thereof. | ☐The learner was able to identify all parts successfully and knew the purpose of most of the parts. | ☐The learner was able to identify all parts successfully and knew the purpose of all the parts. |
| **Conversion of the control circuit to a ladder logic diagram** | ☐The learner was unable to convert the control circuit to a ladder logic diagram. | ☐The learner was able to convert only 1 part of the control circuit to a ladder logic diagram. | ☐The learner was able to convert 2 to 3 parts of the control circuit to a ladder logic diagram. | ☐The learner was able to convert 4 to 5 parts of the control circuit to a ladder logic diagram. | ☐The learner was able to convert all parts of the control circuit to a ladder logic diagram successfully. |
| **Writing a PLC program** | ☐The learner was unable to write a PLC program. | ☐The learner was able to write only 1 instruction of the program. | ☐The learner was able to write 2 to 3 instructions of the program. | ☐The learner was able to write 4 to 5 instructions of the program. | ☐The learner was able to write all instructions of the program successfully. |
| **Downloading and running** | ☐The learner was unable to download and run the program on the PLC. **(0 marks)** | | ☐The learner was able to download and run the program on the PLC with some assistance from the teacher. **(2 marks)** | | ☐The learner was able to download and run the program on the PLC without any assistance from the teacher. **(5 marks)** |
| **Trouble-shooting of the program (only if the program did not run)** | ☐The learner could not trouble-shoot at all. | ☐The learner was able to trouble-shoot after 4 attempts. | ☐The learner was able to trouble-shoot after 3 attempts. | ☐The learner was able to trouble-shoot after 2 attempts. | ☐The learner's program worked after the first attempt. **(5 marks)** |
| **Main circuit wiring and running of the PLC** | ☐The learner was unable to wire the main circuit. | ☐The learner was able to wire the main circuit partly correct, but did not use overload protection. | ☐The learner was able to wire the main circuit, including overload protection, but did not know why it was used. | ☐The learner was able to wire the main circuit and test the overload protection and had a working knowledge of the circuit. | ☐The learner was able to test the main circuit correctly after assembly and had a well-founded knowledge of all the working parts. The learner was able to re-assemble the circuit quickly and accurately without the aid of the circuit diagram |
| **Running the motor using the PLC main circuit working** | ☐The circuit did not work. | ☐The circuit worked after some trouble-shooting. The main circuit had to be corrected OR the PLC programming had to be altered. **(4 marks)** | | | ☐The circuit worked. The main circuit was wired correctly and the PLC operated correctly. **(10 marks)** |
| **Safety** | ☐The learner did not work safely. | ☐The learner worked safely after being reprimanded. | ☐The learner worked safely under supervision of the teacher. | ☐The learner worked safely without being reminded by the teacher. | ☐The learner was able to work safely without supervision or being reminded by the teacher. Safety was excellent. |
| **Housekeeping** | ☐The learner did no housekeeping. | ☐The learner did housekeeping under duress. | ☐The learner did housekeeping under the supervision of the teacher. | ☐The learner did housekeeping after she/he was reminded by the teacher. | ☐The learner was able to do housekeeping without supervision or being reminded by the teacher. Housekeeping was done excellently. |
| | | | | **Total of the Rubric (Maximum of 50)** | |

**Electronic – 1**

Simulation 6 Time: 3 hours

Learner Name: _____

School: _____

Examination Number: _____

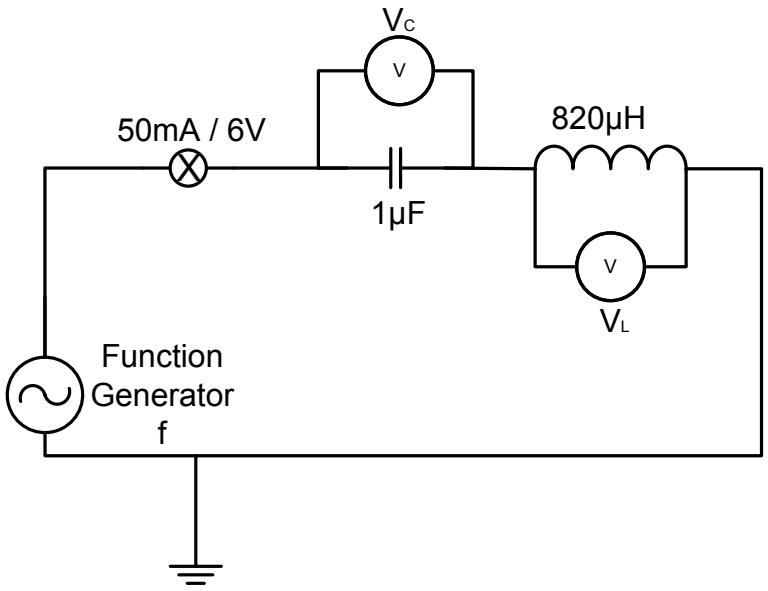
**RLC series circuit**

1. **Purpose:**
To investigate the voltages across a lamp, inductor and a capacitor at a specific voltage setting and a range of frequencies

2. **Equipment:**

| **Description** | **Quantity** |
|---|---|
| Breadboard/Prototype board | 1 |
| Function generator | 1 |
| Dual-channel oscilloscope | 1 |
| Multimeter | 2 |
| Connecting leads | |
| 1 µF capacitor | 1 |
| 50 mA/6 V lamp | 1 |
| 820 µH coil | 1 |

3. **Procedure:**
3.1 Construct the circuit shown below.



3.2 Set the function generator to sine wave and adjust the voltage to around 5 to 6 V. Once the voltage is set do not change the amplitude setting of the voltage.

3.3 Set the amplitude settings on the oscilloscope to the same for both channel 1 and channel 2.

**Operation 1:**
Connect a voltmeter across the coil and a voltmeter across the capacitor.

1. Adjust the frequency of the function generator until the reading on each meter is the same. Record the reading of the frequency and voltages across each component.

| | |
|---|---|
| $V_C$ | |
| $V_L$ | |
| f | |

(3)

2. State the value of the frequency at this setting. Explain why this is this value.

_____

_____

_____ (3)

3. Adjust the frequency above this value and record the values of the voltages across the capacitor and resistor. Describe the reason for the readings on the meters.

| | |
|---|---|
| $V_C$ | |
| $V_L$ | |

_____

_____ (2)

4. Adjust the frequency below this value and record the values of the voltages across the capacitor and resistor. Describe the reason for the readings on the meters.

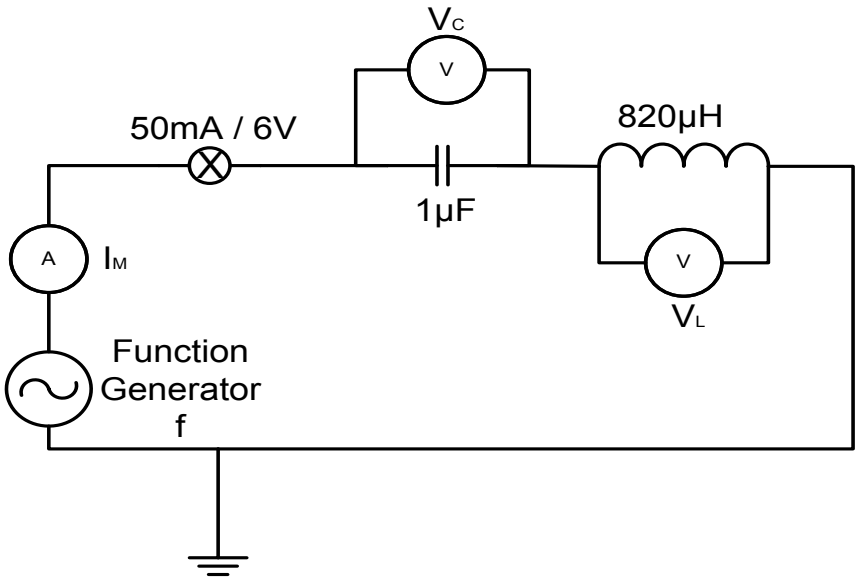
| | |
|---|---|
| $V_C$ | |
| $V_L$ | |

_____

_____ (2)

**SUBTOTAL: 10**

**Operation 2:**
Connect an ammeter in the circuit to measure the current flow in the circuit, as shown below:




1. Adjust the frequency of the function generator until the reading on the meter is at a maximum. Record the reading of the frequency and the current reading.

| | |
|---|---|
| $I_M$ | |
| f | |

(2)

2. Describe the state of the frequency when the current is at a maximum.

_____

_____ (2)

3. Adjust the frequency above this value and record the value of the current. Describe the reason for the reading.

| | |
|---|---|
| I | |

(1)

4. Adjust the frequency below this value and record the value of the current. Describe the reason for the reading.

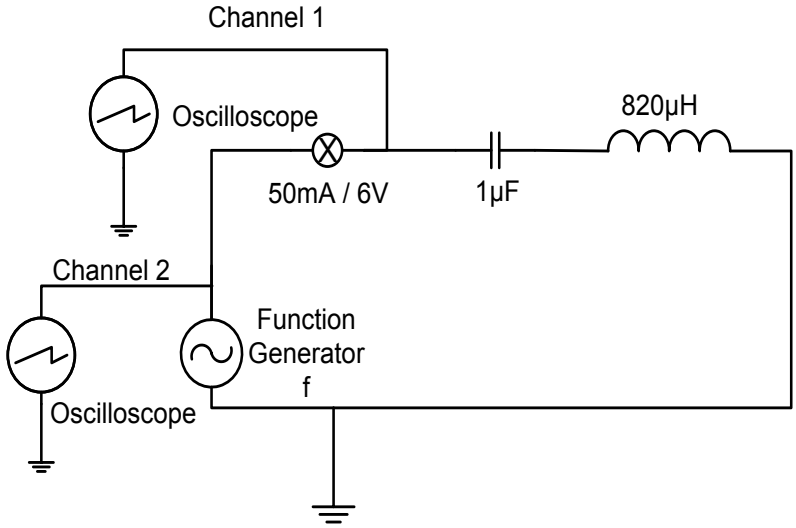
| | |
|---|---|
| I | |

(1)

_____

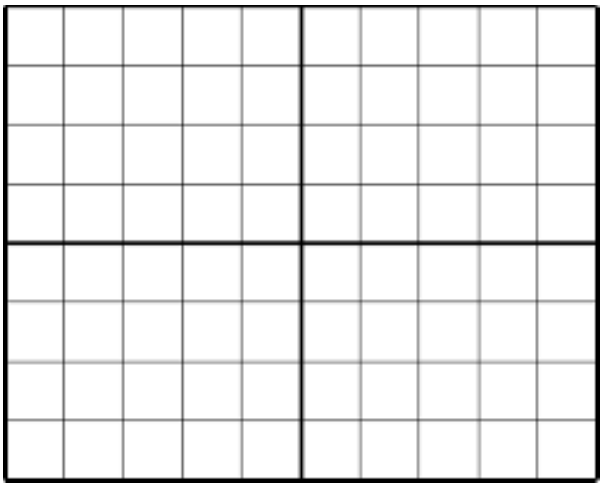
**SUBTOTAL: 6**

**Operation 3:**
Connect the oscilloscope to the circuit, as shown below.
Connect channel 1 across the lamp and channel 2 across the supply.




1. Adjust the frequency of the function generator to obtain resonant frequency by observing the changing waveforms on the oscilloscope.

2. Draw the waveforms at resonant frequency.



(3)

3. Describe why the waveforms are this shape.

_____

_____

_____

_____ (3)

4. Adjust the frequency of the function generator and describe what happens to the shape of the waveforms.

_____

_____

_____ (3)

**SUBTOTAL: 9**

## RUBRIC SIMULATION 6: RLC SERIES CIRCUIT

| Task Description | Mark Allocation (Tick the appropriate level next to the Task Indicated) | | | | |
|---|---|---|---|---|---|
| | **1 Not achieved** | **2 Not competent yet** | **3 Competent** | **4 Highly Competent** | **5 Outstanding** |
| **Circuit diagram drawing** | ☐The learner was unable to draw the circuit diagram | ☐The learner was able to draw the 3 components connected in series. | ☐The learner was able to draw the 3 components connected in series, with the correct meter connections shown. | ☐The learner was able to draw the3 components connected in series, with the correct meter connections and the correct oscilloscope connections shown. | ☐The learner was able to draw the 3 components connected in series, with the correct meter connections and the correct oscilloscope connections shown, and fully labelled. |
| **Breadboard planning and layout** | ☐The learner was unable to plan the board layout using the circuit diagram provided. | ☐The learner was able identify the correct components and meters. | ☐The learner was able to plan and place the 3 components correctly on the breadboard. | ☐The learner was able to plan successfully and place all the components correctly on the breadboard with links. | ☐The learner was able to plan successfully and place all the components correctly on the breadboard connected to the function generator. |
| **Trouble-shooting** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. | ☐The circuit was complete and the learner was able to identify and rectify all the mistakes. |
| **Circuit operation** | ☐The circuit did not work at all. **(0 marks)** | | ☐The circuit worked after more than 1 try. **(2 marks)** | | ☐The circuit worked first time. **(5 marks**) |
| **Instrument selection and use** | ☐The learner was unable to select and use any instruments. | ☐The learner selected and used the incorrect instruments. | ☐The learner was able to select the correct instruments, but used them incorrectly/ unsafely. | ☐The learner was able to select all instruments correctly and used them correctly. | ☐The learner selected instruments quickly and without the help of the teacher. The learner was also able to use instruments correctly in a safe ergonomic manner. |
| | | | | **Rubric (25)** | |
| | | | | **Operation 1 (10)** | |
| | | | | **Operation 2 (6)** | |
| | | | | **Operation 3 (9)** | |
| | | | | **Total (50)** | |

**Electronic – 2**

Simulation 7 Time: 3 hours

Learner Name: _____

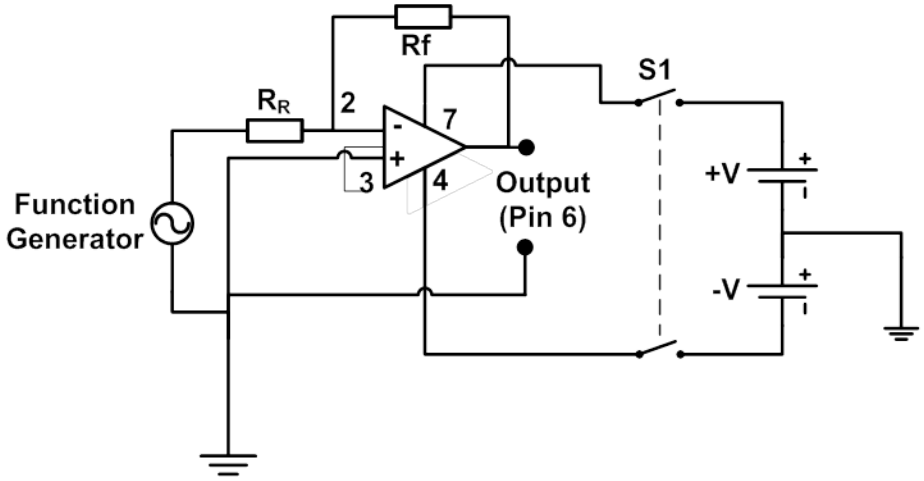
School: _____

Examination Number: _____

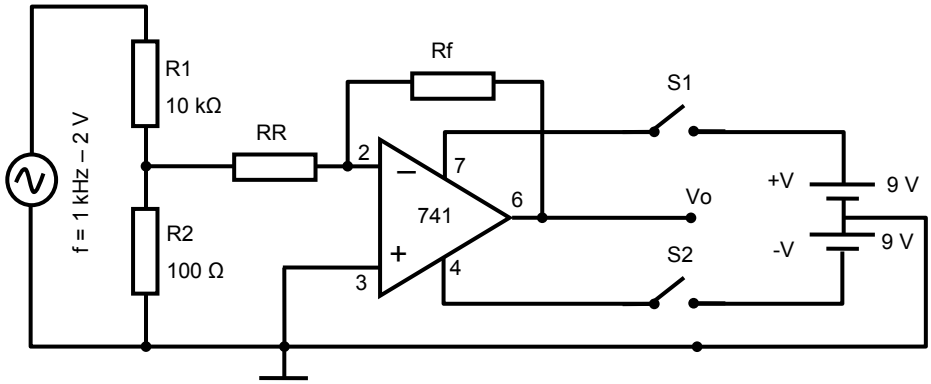
**Gain of an operational amplifier**

1. **Purpose:**
To determine the gain of an operational amplifier mathematically and practically.

2. **Circuit diagram:**




(Alternative circuit below)



3. **Equipment:**
   - Breadboard/Protoboard
   - Hook-up wire
   - 741 op amp and components
   - Oscilloscope – dual trace
   - Function generator
   - Tools to build circuit
   - Split power supply (or two 9 V batteries) (+9 V/0 V/-9 V)

4. **Procedure:**
   - Connect the circuit shown above with $R_f = R_R = 100\ k\Omega$ on a breadboard.
   - S1 is open.
   - Set each of the two voltage supplies to 9 volts.
   - Set the function generator to 1 000 Hz. Reduce the gain to zero output or as close as you can.
   - Connect trace/channel 2 of the oscilloscope to the output of the op amp.(Pin 6 and 0 V)
   - Trigger/Sync the oscilloscope to show the wave form.
   - Connect the input wave from the function generator to trace/channel 1 of the oscilloscope. (Function generator)
   - Close S1, applying power to the circuit.
   - Slowly increase the output of the function generator to just below the point where the output signal is being distorted. (Look at both the input and the output waveforms and compare the shape to see if the output is being distorted.)
   - With the oscilloscope measure and record the output voltage $V_{out}$ from the amplifier (output pin 6) **(peak-to-peak value)**.
   - With the oscilloscope measure and record the input voltage $V_{in}$ to the amplifier (output of the signal generator) **(peak-to-peak value)**.
   - Calculate the gain of the amplifier and record it in the table.
   - Compare the input and output wave forms and determine whether or not they are in or out of phase with each other (0º or 180º).
   - Reduce the output of the function generator to zero.
   - Repeat the experiment, each time replacing $\mathbf{R_R}$ with the values shown in the table.

5. **Measurements:**

| **Rf** Ω | **$R_R$** Ω | **$V_{P-P}$** | | **Gain** $A = \frac{Vout}{Vin}$ | **In phase with input?** | |
|---|---|---|---|---|---|---|
| | | **Output** | **Input** | | | |
| 10 000 | 100 000 | | | | | Control |
| | 50 000 | | | | | (4) |
| | 33 000 | | | | | (4) |
| | 24 000 | | | | | (4) |
| | 200 000 | | | | | (4) |
| | 300 000 | | | | | (4) |

(The last two values will have to be made up using different resistors.)

6. **Housekeeping:**
On completion place all instruments and tools back and apply housekeeping.

7. **Conclusion:**
There is a strong correlation between calculated and measured values. Discrepancies in measurements and calculations can be attributed to component tolerances.

**SUBTOTAL: 20**

## RUBRIC ELECTRONIC SIMULATION 2: GAIN OF AN OP AMP

| **Task Description** | **Mark Allocation** (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | **1 Not achieved** | **2 Not competent yet** | **3 Competent** | **4 Highly competent** | **5 Outstanding** |
| **Breadboard planning and layout** | ☐The learner was unable to plan the board layout using the circuit diagram supplied. | ☐The learner was able to plan correctly and place 4 or fewer components correctly on the board. | ☐The learner was able to plan correctly and place more than 4, but fewer than 8 components correctly on the board. | ☐The learner was able to plan successfully and place all the components correctly on the board with links. | ☐The learner was able to plan successfully and place all the components on the board correctly considering space used, alignment of components and component types. |
| **Trouble-shooting** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but was not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. | ☐The circuit was complete and the learner was able to identify and rectify all the mistakes. |
| **Component selection and identification** | ☐The learner was unable to identify and select any components. | ☐The learner was able to identify and select fewer than 4 components. | ☐The learner was able to select more than 4, but fewer than 8 components. | ☐The learner was able to identify and select all components. | ☐The learner identified and selected components quickly and without the help of the teacher. The learner was also able to identify equivalent values using a variety of methods. |
| **Instrument selection and use** | ☐The learner was unable to select and use any instruments. | ☐The learner selected and used the incorrect instruments. | ☐The learner was able to select the correct instruments, but used them incorrectly/ unsafely. | ☐The learner was able to select and use all the instruments correctly. | ☐The learner selected instruments quickly and without the help of the teacher. He/She was also able to use the instruments correctly in a safe ergonomic manner. |
| **Housekeeping** | ☐The learner did no house-keeping. | ☐The learner did the housekeeping under duress. | ☐The learner did housekeeping under the supervision of the teacher. | ☐The learner did housekeeping after she/he was reminded by the teacher. | ☐The learner was able to do housekeeping without supervision or being reminded by the teacher. Housekeeping was done excellently. |
| **Safety** | ☐The learner did not work safely. | ☐The learner worked safely after being reprimanded. | ☐The learner worked safely under the supervision of the teacher. | ☐The learner worked safely without being reminded by the teacher. | ☐The learner was able to work safely without supervision or being reminded by the teacher. Safety was excellent. |
| | | | | **Rubric (Maximum of 30)** | |
| | | | | **Measurements (20)** | |
| | | | | **Total (Maximum of 50)** | |

**Electronic – 3**

Simulation 8 Time: 3 hours

Learner Name: _____

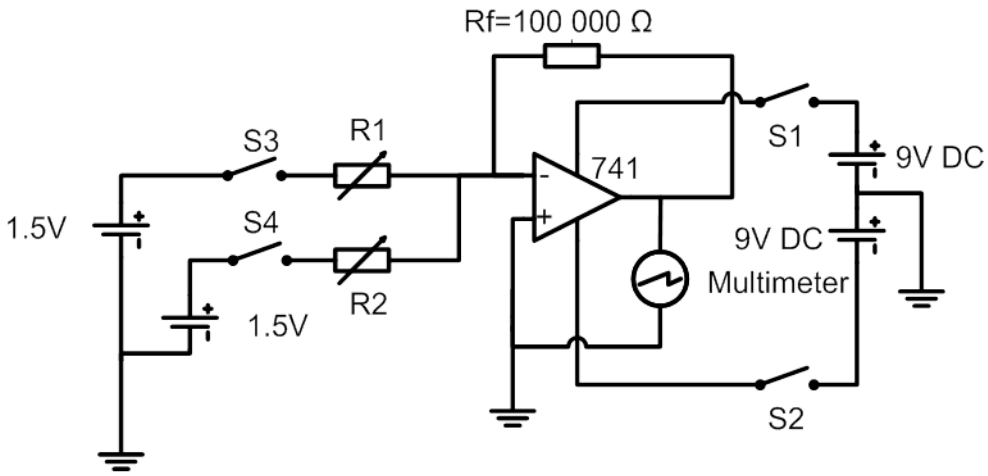
School: _____

Examination Number: _____

**Experimental summer circuit**

1. **Purpose:**
   To examine the properties of a summer circuit

2. **Circuit diagram[1]:**




3. **Equipment:**
   - Breadboard/Protoboard
   - Hook-up wire
   - 741 op amp and components
   - Multimeter
   - Tools
   - Split power supply (or two 9 V batteries)

[1] Ref: *Basic Electronics: A Text Lab Manual*: Paul B Zbar, Albert P Malvino, McGraw Hill

4. **Procedure:**

**Step 1**

- Connect the circuit shown above.
- Use 1,5 V cells to supply S2 and S3.
- S1 is open.

**Step 2**

- Set each of the two voltage supplies to 9 volts.
- Leave switches S2 and S3 off (open).

**Step 3**

- Switch the circuit on (S1).

Complete the table below for all the possible positions for S2 and S3.

| Condition | | Input polarity | | Vin | | $V_{out}$ at pin 6 | |
|---|---|---|---|---|---|---|---|
| **S2** | **S3** | $V_{S2}$ | $V_{S3}$ | $V_{S2}$ | $V_{S3}$ | | |
| On | Off | + | | | | | (2) |
| Off | On | | + | | | | (2) |
| On | On | + | + | | | | (3) |
| On | On | - | + | | | | (3) |

Note the polarity of the input voltages in each case.

5. **Housekeeping:**

On completion put away all instruments and tools and apply housekeeping.

6. **Conclusion:**

Electrical voltage values can be added or subtracted from each other, similar to the addition and subtraction of mathematical values.

**Subtotal: 10**

## RUBRIC ELECTRONIC SIMULATION 8: EXPERIMENTAL SUMMER CIRCUIT

| **Task Description** | **Mark Allocation** (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | **1 Not achieved** | **2 Not competent yet** | **3 Competent** | **4 Highly competent** | **5 Outstanding** |
| **Breadboard planning and layout** | ☐The learner was unable to plan the board layout using the circuit diagram supplied. | ☐The learner was able to plan correctly and place 4 or fewer components correctly on the breadboard. | ☐The learner was able to plan correctly and place more than 4, but fewer than 8 components correctly on the breadboard. | ☐The learner was able to plan successfully and place all the components correctly on the breadboard with links. | ☐The learner was able to plan successfully and place all the components correctly on the breadboard considering space used, alignment of components and component types. |
| **Trouble-shooting** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. | ☐The circuit was complete and the learner was able to identify and rectify all mistakes. |
| **Circuit operation** | ☐The circuit did not work at all. **(0 marks)** | | ☐The circuit worked after more than one try. **(3 marks)** | | ☐The circuit worked first time. **(5 marks**) |
| **Component selection and identification** | ☐The learner was unable to identify and select any components. | ☐The learner was able to identify and select fewer than 4 components. | ☐The learner was able to select more than 4, but fewer than 8 components. | ☐The learner was able to identify and select all components. | ☐The learner identified and selected components quickly and without the help of the teacher. The learner was also able to identify equivalent values using a variety of methods. |
| **Instrument selection and use** | ☐The learner was unable to select and use any instruments. | ☐The learner selected and used the incorrect instruments. | ☐The learner was able to select the correct instruments, but used them incorrectly/ unsafely. | ☐The learner was able to select and use all the instruments correctly. | ☐The learner selected instruments quickly and without the help of the teacher. The learner was also able to use instruments correctly in a safe ergonomic manner. |
| **House-keeping** | ☐The learner did no house-keeping. | ☐The learner did house-keeping under duress. | ☐The learner did house-keeping under the supervision of the teacher. | ☐The learner did house-keeping after she/he was reminded by the teacher. | ☐The learner was able to do housekeeping without supervision or being reminded by the teacher. Housekeeping was done excellently. |
| **Safety** | ☐The learner did not work safely. | ☐The learner worked safely after being reprimanded. | ☐The learner worked safely under supervision of the teacher. | ☐The learner worked safely without being reminded by the teacher. | ☐The learner was able to do work safely without supervision or being reminded by the teacher. Safety was excellent. |
| | | | | **Rubric (Maximum of 40)** | |
| | | | | **Measurements (10)** | |
| | | | | **Total (Maximum of 50)** | |

**Digital – 1**

Simulation 9 Time: 3 hours

Learner Name: _____

School: _____

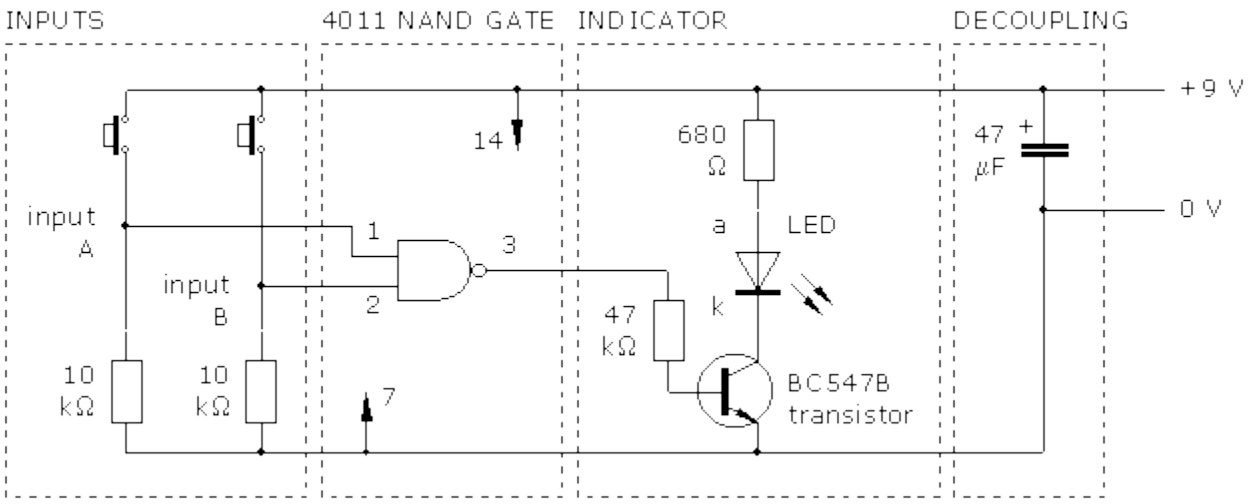
Examination Number: _____

**NAND gate applications**

1. **Purpose:**
   To practise the use of NAND gates in logic circuits.

2. **Equipment:**
   - Breadboard
   - 9 V power supply
   - Miniature tactile switch x2
   - BC547B NPN transistor
   - 680 Ω resistor
   - 47 kΩ resistor
   - 10 kΩ resistor x2
   - 47µF capacitor
   - 4011 IC

3. **The circuit: NAND gate indicator**




4. **Procedure:**
   - Investigate the behaviour of a single NAND gate using the 4011 Quad 2-input NAND gate IC.
   - Investigate a universal property of a NAND gate.

5. **Part A: Procedure**

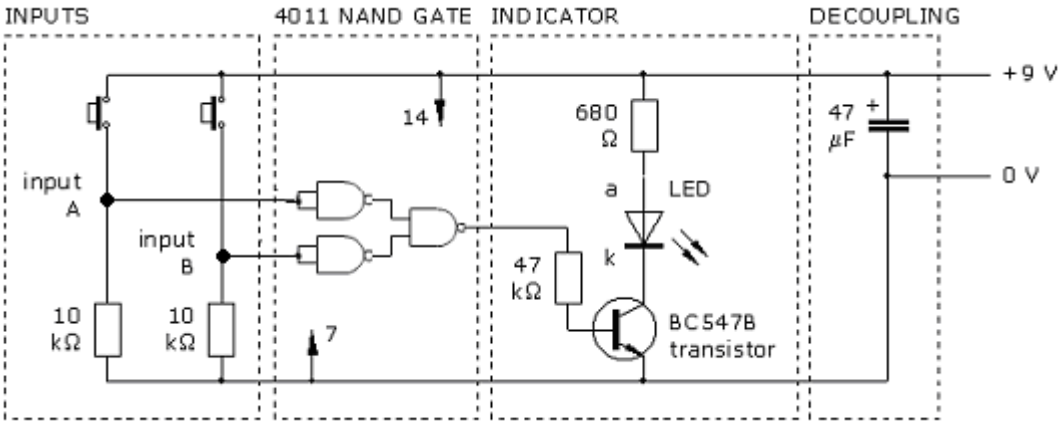
- Assemble the NAND gate indicator, as shown below.
- The inputs of the gate must be connected, either to LOW or to HIGH, and must NOT be left open circuit. This is the function of the input switches with their pull-down resistors.
- To avoid loading the output of the gate, a transistor switch indicator circuit should be used.
- It is good practice with CMOS circuits to insert a decoupling capacitor, 47 µF or 100 µF, across the power supply. (This helps to prevent the transfer of spikes along the power supply rails.)
- Complete the truth table (1 = Input Switch On and 0 = Input Switch Off)

| Input A | Input B | Output – LED |
|---|---|---|
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

(4)

6. **Part B: Procedure**

Modify your existing NAND gate circuit to the combinational NAND gate circuit, as in the diagram shown below.




Operate the Input A and Input B switches to confirm the output action of the circuit.

| Input A | Input B | Output – LED |
|---|---|---|
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

(4)

This combination of NAND gates operates the same as a … gate. (2)

6. **Conclusion:**

NAND gates can be combined to simulate any Boolean expression.

**SUBTOTAL: 10**

## RUBRIC DIGITAL SIMULATION 9: NAND GATE APPLICATIONS

| **Task Description** | **Mark Allocation** (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | **1**<br>**Not achieved** | **2**<br>**Not competent yet** | **3**<br>**Competent** | **4**<br>**Highly competent** | **5**<br>**Outstanding** |
| **Component selection and identification** | ☐The learner was unable to identify and select any components. | ☐The learner was able to identify and select fewer than 4 components. | ☐The learner was able to select more than 4, but fewer than 8 components. | ☐The learner was able to identify and select all components. | ☐The learner identified and selected components quickly and without the help of the teacher. The learner was also able to identify equivalent values using a variety of methods. |
| **Breadboard planning and layout** | ☐The learner was unable to plan the board layout using the circuit diagram supplied. | ☐The learner was able to plan correctly and place 4 or fewer components correctly on the breadboard. | ☐The learner was able to plan correctly and place more than 4, but fewer than 8 components, correctly on the breadboard. | ☐The learner was able to plan successfully and place all the components correctly on the breadboard with links. | ☐The learner was able to plan successfully and place all the components on the breadboard correctly considering space used, alignment of components and component types. |
| **Trouble-shooting** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. | ☐The circuit was complete and the learner was able to identify and rectify all mistakes. |
| **PART A: Circuit operational** | ☐Not operational **(0 marks)** | | | | ☐Operational **(5 marks)** |
| **PART B: Circuit operational** | ☐Not operational **(0 marks)** | | | | ☐Operational **(5 marks)** |
| **Instrument selection and use** | ☐The learner was unable to select and use any instruments. | ☐The learner selected and used the incorrect instruments. | ☐The learner was able to select the correct instruments, but used them incorrectly/ unsafely. | ☐The learner was able to select and use all the instruments correctly. | ☐The learner selected instruments quickly and without the help of the teacher. The learner was also able to use instruments correctly in a safe ergonomic manner. |
| **Tool selection and use** | ☐The learner was unable to select and use any tools. | ☐The learner selected and used the incorrect tools. | ☐The learner was able to select the correct tools, but used them incorrectly/ unsafely. | ☐The learner was able to select and use all the tools correctly | ☐The learner selected tools quickly and without the help of the teacher. The learner was also able to use tools correctly in a safe ergonomic manner. |
| **House-keeping** | ☐The learner did no house-keeping. | ☐The learner did house-keeping under duress. | ☐The learner did house-keeping under the supervision of the teacher. | ☐The learner did house-keeping after she/he was reminded by the teacher. | ☐The learner was able to do housekeeping without supervision or being reminded by the teacher. Housekeeping was done excellently. |
| | | | | **Rubric (Maximum of 40)** | |
| | | | | **NAND gates (Maximum of 10)** | |
| | | | | **Total (Maximum van 50)** | |

**Digital – 2**

Simulation 10 Time: 3 hours

Learner Name: _____

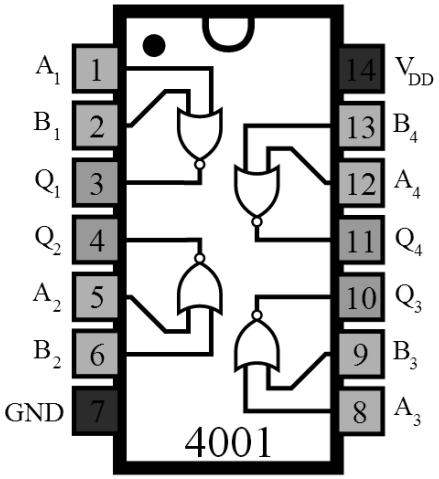
School: _____

Examination Number: _____

**NOR gate application**

1. **Purpose:**
To practise the application of NOR gates in logic circuits.

2. **The 4001 Logic IC[2]:**



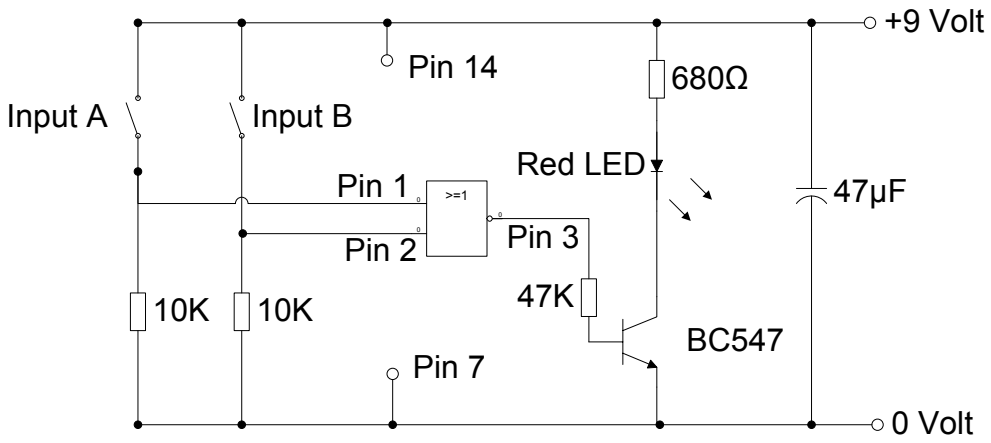

The truth table of each individual gate is that of a NOR gate truth table.

| A | B | X |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

'0' represents a LOW voltage and '1' represents a HIGH voltage.

[2] Ref: www.doctronics.com

The circuit below uses the 4001 CMOS IC to investigate the behaviour of the NOR gate




**Step 1 – Build the NOR gate test circuit**

- The inputs of the gate MUST be connected, either to LOW or to HIGH, and MUST NOT be left open circuit.
- This is the function of the input switches with their pull-down resistors.
- To avoid loading the output of the gate, a transistor switch indicator circuit should be used.
- It is good practice with CMOS circuits to insert a decoupling capacitor, 47 µF or 100 µF, across the power supply. (This helps to prevent the transfer of spikes along the power supply rails.)
- Do not forget to connect pin 14 of the 4001 to +9 V and pin 7 to 0 V.

| Component connected correctly | Maximum marks | ☑/☒ |
|---|---|---|
| Supply polarity | 1 | ☐ |
| Capacitor polarity | 1 | ☐ |
| Transistor | 1 | ☐ |
| Pin 14/Pin 7 correct | 1 | ☐ |
| NOR gate pins | 1 | ☐ |

(5)

**NOTE:**
In the prototype circuit, it is not essential to make connections to the unused gates. However, in any final circuit, all unused CMOS inputs must be connected either too HIGH or too LOW.

Make it an absolute rule that CMOS inputs are NEVER left open circuit. There is no problem with CMOS outputs. Worry about the inputs and leave any unused outputs unconnected.

**Step 2**

- Use the 4001 IC and build a logic circuit that will represent the following Boolean function.

$$A + B = X$$

- Circuit design
  - Draw the logic gate circuit using NOR gates in the block provided below. (Include the power connections to the IC and external components you will use.)

| Design drawn correctly | Maximum marks | ☑/☒ |
|---|---|---|
| Supply polarity | 1 | ☐ |
| Capacitor polarity | 1 | ☐ |
| Transistor on output | 1 | ☐ |
| Pin 14/Pin 7 correct | 1 | ☐ |
| Circuit design correct (will operate) | 1 | ☐ |

(5)

- Now build the circuit on a breadboard and check if the circuit operates correctly.

| Component connected correctly according to design | Maximum marks | ☑/☒ |
|---|---|---|
| Supply polarity | 1 | ☐ |
| Capacitor polarity | 1 | ☐ |
| Transistor | 1 | ☐ |
| Pin 14/Pin 7 correct | 1 | ☐ |
| NOR gate pins correct | 1 | ☐ |

(5)

- Now fill the truth table according to the functioning of the circuit you designed. Press the switches to simulate the inputs and use a LED ON as 1 and LED OFF as 0.

| A | B | X |
|---|---|---|
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

(4)

3. **Conclusion:**

_____

_____ (1)

**SUBTOTAL: 20**

## RUBRIC DIGITAL SIMULATION 10: NOR GATE APPLICATION

| Task Description | Mark Allocation (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | 1 Not achieved | 2 Not competent yet | 3 Competent | 4 Highly Competent | 5 Outstanding |
| **Breadboard planning and layout** | ☐The learner was unable to plan the board layout using the circuit diagram supplied. | ☐The learner was able to plan correctly and place 4 or less components on the board correctly. | ☐The learner was able to plan correctly and place more than 4, but fewer than 8 components on the board correctly. | ☐The learner was able to plan successfully and place all the components on the board correctly with links. | ☐The learner was able to plan successfully and place all the components on the board correctly considering space used, alignment of components and component types. |
| **Trouble-shooting** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. | ☐The circuit was complete and the learner was able to identify and rectify all mistakes. |
| **Component selection and identification** | ☐The learner was unable to select and identify any components. | ☐The learner was able to select and identify fewer than 4 components. | ☐The learner was able to select and identify more than 4, but fewer than 8 components. | ☐The learner was able to select and identify all components. | ☐The learner identified and selected components quickly and without the help of the teacher. The learner was also able to identify equivalent values using a variety of methods. |
| **Tool selection and use** | ☐The learner was unable to select and use any tools. | ☐The learner selected and used the incorrect tools. | ☐The learner was able to select the correct tools, but used them incorrectly/ unsafely. | ☐The learner was able to select and use all the tools correctly. | ☐The learner selected tools quickly and without the help of the teacher. The learner was also able to use the tools correctly in a safe ergonomic manner. |
| **Housekeeping** | ☐The learner did no house-keeping. | ☐The learner did house-keeping under duress. | ☐The learner did housekeeping under the supervision of the teacher | ☐The learner did housekeeping after she/he was reminded by the teacher. | ☐The learner was able to do housekeeping without supervision or being reminded by the teacher. Housekeeping was done excellently. |
| **Safety** | ☐The learner did not work safely. | ☐The learner worked safely after being reprimanded. | ☐The learner worked safely under supervision of the teacher. | ☐The learner worked safely without being reminded by the teacher. | ☐The learner was able to work safely without supervision or being reminded by the teacher. Safety was excellent. |
| | | | | **Rubric (Maximum of 30)** | |
| | | | | **Working Circuits (Maximum of 20)** | |
| | | | | **Total (Maximum of 50)** | |

**Digital – 3**

Simulation 11 Time: 3 hours

**Learner Name:** _____

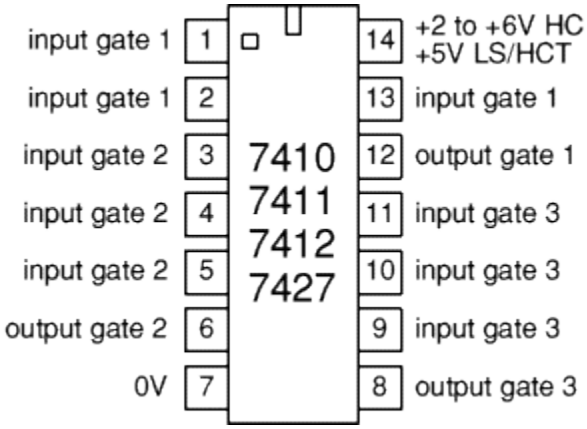
**School:** _____

**Examination Number:** _____

**NOR gate application using the 7427**

1. **Purpose:**
   To illustrate that not all logic gates use 2 inputs only

2. **The 7427 logic IC:**




**NOTE:** This IC can handle up to 6 V DC only.

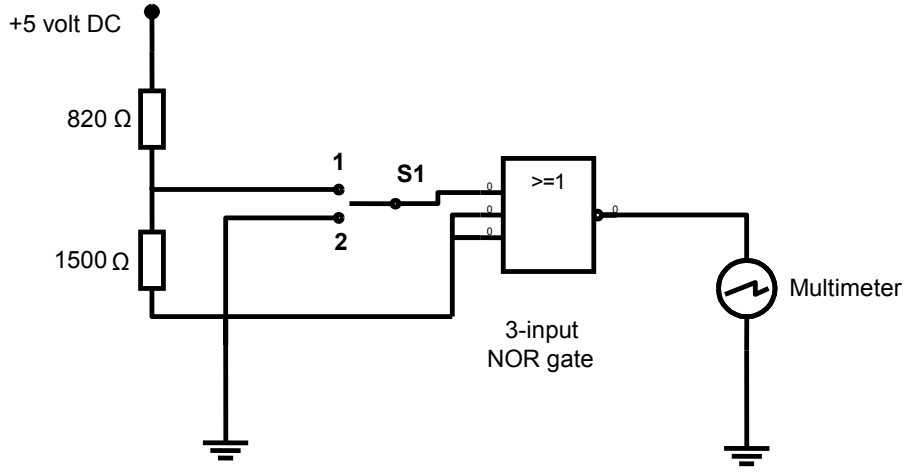
3. **Equipment:**
   - Regulated power supply
   - Multimeter
   - Components
   - 7427 triple, three-input NOR gate IC
   - 820 Ω resistor
   - 1 500 Ω resistor
   - 3 x SPDT switches
   - Breadboard
   - Hook-up wire

4. **Procedure:**

**Circuit 1: Simple NOR gate**

- Connect one of the NOR gates of the 7427, as shown below.
- The voltage divider provides the proper DC levels for the IC.
- Positive Logic 1 = 2,4–5 volts
- Positive Logic 0 = 0–0,5 volts
- S1 provides between 0 and 3,2 volts to the IC depending on its state.




| Circuit connected correctly | Maximum marks | ☑/☒ |
|---|---|---|
| Supply polarity | 1 | ☐ |
| Multimeter polarity | 1 | ☐ |
| Multimeter setting | 1 | ☐ |
| Pin identification | 1 | ☐ |
| Resistor placement | 1 | ☐ |

(5)

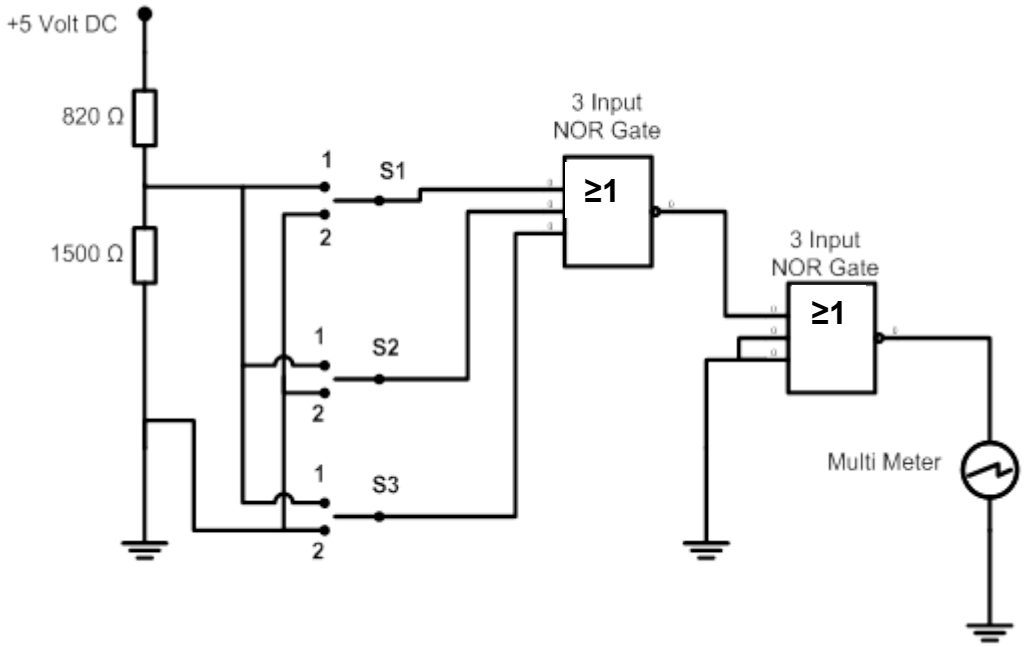
- Complete the truth table.

| S1 | Multimeter reading |
|---|---|
| Position 1 | |
| Position 2 | |

(2)

**Procedure:**
**Circuit 2: Dual 3-input NOR gate combination**

- Connect the NOR gates of the 7427, as shown below.
- The voltage divider provides the proper DC levels for the IC.
- Positive Logic 1 = 2,4–5 volts
- Positive Logic 0 = 0–0,5 volts
- S1, S2 and S3 provides between 0 and 3,2 volts to the IC depending on its state.
- Complete the truth table.
- Derive the Boolean expression from the circuit.




| S1 = A | S2 = B | S3 = C | Multimeter = D | |
|---|---|---|---|---|
| 0 | 0 | 0 | | (1) |
| 0 | 0 | 1 | | (1) |
| 0 | 1 | 0 | | (1) |
| 0 | 1 | 1 | | (1) |
| 1 | 0 | 0 | | (1) |
| 1 | 0 | 1 | | (1) |
| 1 | 1 | 0 | | (1) |
| 1 | 1 | 1 | | (1) |

Boolean expression = _____ (5)

5. **Conclusion:**
Logic gates can be adapted to have more than just 2 inputs. There are devices with multiple inputs to a logic gate.

**SUBTOTAL OF CIRCUITS: 20**

## RUBRIC FOR DIGITAL SIMULATION 11: NOR GATE APPLICATION USING THE 7427

| **Task Description** | **Mark Allocation** (Tick the appropriate level next to the task indicated) | | | | |
|---|---|---|---|---|---|
| | **1 Not achieved** | **2 Not competent yet** | **3 Competent** | **4 Highly competent** | **5 Outstanding** |
| **Trouble-shooting** | ☐The learner's circuit was not complete and she/he was unable to conduct trouble-shooting. | ☐The circuit was complete, but not functional. The learner was unable to identify the problem. | ☐The circuit was complete and the learner was able to identify and rectify 1 mistake. | ☐The circuit was complete and the learner was able to identify and rectify 2 mistakes. | ☐The circuit was complete and the learner was able to identify and rectify all the mistakes. |
| **Circuit 1: Operational** | ☐The circuit did not work. **(0 marks)** | | | | ☐The circuit worked. **(5 marks)** |
| **Circuit 2: Operational** | ☐The circuit did not work. **(0 marks)** | | | | ☐The circuit worked. **(5 marks)** |
| **Instrument use** | ☐The learner was unable to identify or use any instruments correctly. | ☐The learner identified and used the incorrect instruments. | ☐The learner was able to select the correct instruments, but used them incorrectly/ unsafely. | ☐The learner was able to identify, select and use all the instruments correctly. | ☐The learner identified and selected instruments quickly and without the help of the teacher. The learner was also able to use instruments correctly in a safe ergonomic manner. |
| **House-keeping** | ☐The learner did no house-keeping. | ☐The learner did house-keeping under duress. | ☐The learner did housekeeping under the supervision of the teacher | ☐The learner did housekeeping after she/he was reminded by the teacher. | ☐The learner was able to do house-keeping without supervision or being reminded by the teacher. House-keeping was done excellently. |
| **Safety** | ☐The learner did not work safely. | ☐The learner worked safely after being reprimanded. | ☐The learner worked safely under supervision of the teacher. | ☐The learner worked safely without being reminded by the teacher. | ☐The learner was able to work safely without supervision or being reminded by the teacher. Safety was excellent. |
| | | | | **Rubric (Maximum of 30)** | |
| | | | | **Circuits Subtotal (Maximum of 20)** | |
| | | | | **Total (Maximum of 50)** | |

**Digital – 4**

Simulation 12 Time: 3 hours

Learner Name: _____

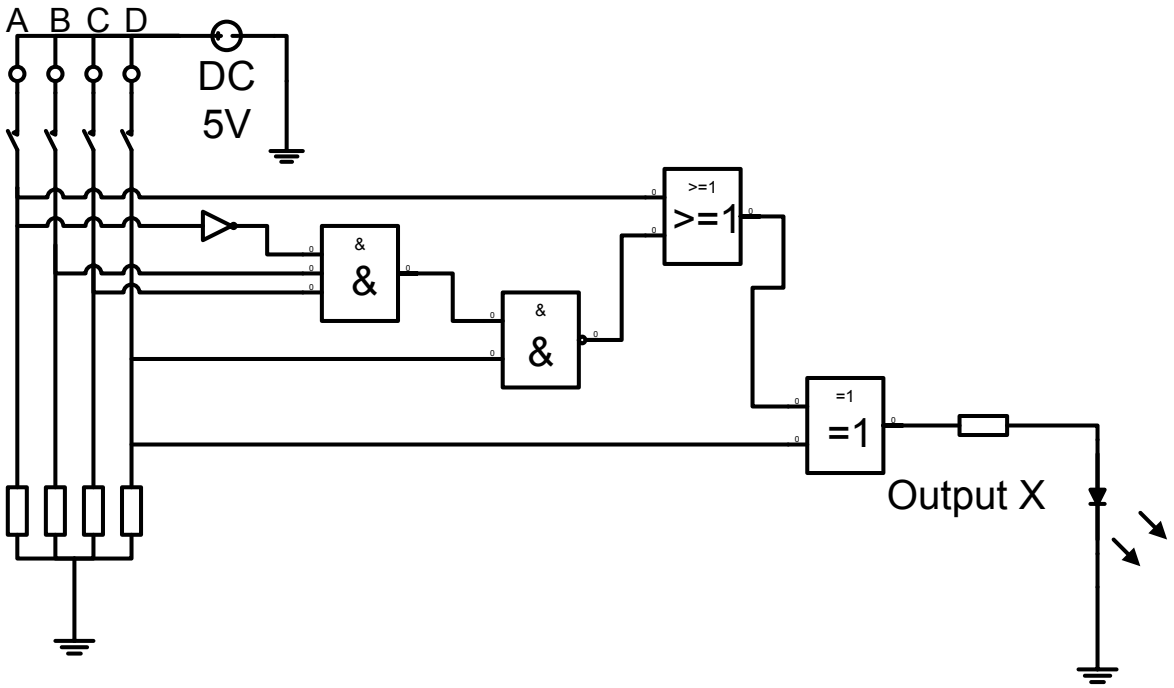
School: _____

Examination Number: _____

**Boolean algebra**

1. **Purpose:**
To test Boolean algebra and construct an electronic circuit that simulates a Boolean expression.

2. **Procedure:**
Determine the Boolean equation for the following logic gate circuit:




(7)

3. Draw the logic gate circuit for the Boolean equation $X = \overline{(A+B)}\ \overline{C}$

(5)

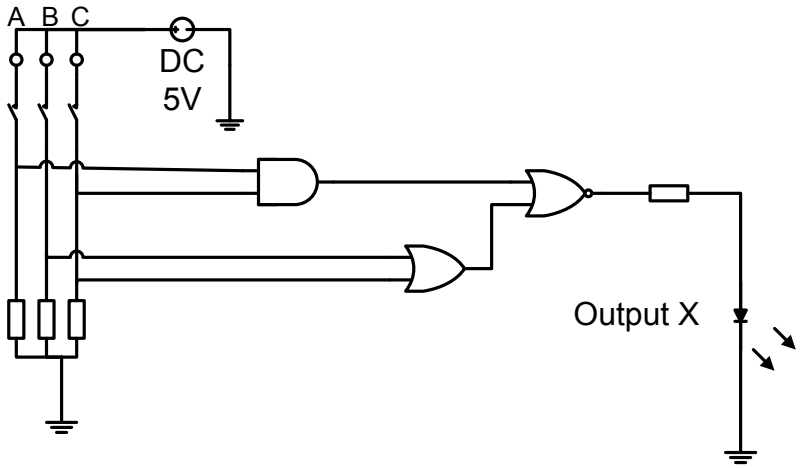
4. Determine the Boolean equation for the truth table below:

| A | B | C | X |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 |

X=

(4)

5. Redraw the circuit below using NAND gate combinations:




(5)

6. Use De Morgan's Theorem and prove that the LHS = RHS. (Show ALL steps.)

$\overline{A.B.\overline{C}} = \overline{A.B} + C$

(5)

7. Simplify the Boolean equation below. (Show ALL steps.)

$$Z = (A + \bar{B} + \bar{C})(B.\bar{C})$$

(7)

8. Using a Karnaugh map, simplify the following truth table and give the final Boolean expression:

| A | B | C | X |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | | 1 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 |

| | 0 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | | | |
| 1 | | | | |

X = _____ (9)

9. **Construct**, **on a breadboard**, a logic circuit using a logic IC to form a logic gate network that will satisfy the Boolean expression shown below.
X must be represented by an LED which will light up when X = 1 and when X = 0 the LED will not light up.
(Schools with PLCs may opt to simulate this question on PLC.)

$$(A + B) + C.\overline{D} = X$$

**Circuit Design**

(8)

10. **Conclusion:**
Boolean algebra equations can be constructed and applied electronically.

**TOTAL: 50**

## ANNEXURE: COMPONENT LIST FOR ELECTRONIC/DIGITAL SIMULATIONS

| Component List – Gain of an Op Amp | |
|---|---|
| IC | 741 op amp |
| Rf | 10 K ¼ W 5% |
| Rr1 | 10 K ¼ W 5% |
| Rr2 | 5 K ¼ W 5% |
| Rr3 | 3k3 ¼ W 5% |
| Rr4 | 2k4 ¼ W 5% |
| Rr5 | 20k ¼ W 5% |
| Rr6 | 30k ¼ W 5% |
| S1 | DPST toggle switch |

| Component List – Experimental Summer Circuit | |
|---|---|
| Rf | 10 K ¼ W 5% |
| S1 | DPST toggle switch |
| S2, S3 | SPST toggle switch |
| 1,5 V source | 1,5 V battery |
| Bat. holder | 1 x battery holder |
| R1, R2 | 50 K Pot |

| Component List – NAND Gate Applications | |
|---|---|
| T1 | BC 547 |
| S1, S2 | Tactile push-to-make N/O switch |
| R1 | 680 ohm ¼ W 5% |
| R2 | 47 K ¼ W 5% |
| R3, R4 | 10 K ¼ W 5% |
| C1 | 47 uF 16 V |
| IC1 | 4011 NAND gate IC DIP package |
| D1 | Red LED |

| Component List – NOR Gate Application | |
|---|---|
| IC1 | 4001 NOR gate IC DIP package |
| T1 | BC 547 |
| S1, S2 | Tactile push-to-make N/O switch |
| R1 | 680 ohm ¼ W 5% |
| R2 | 47 K ¼ W 5% |
| R3, R4 | 10 K ¼ W 5% |
| C1 | 47 uF 16 V |
| D1 | Red LED |

| Component List – NOR Gate using the 7427 | |
|---|---|
| IC1 | 7427 Quad 3 input NOR gate – DIP package |
| R1 | 820 ohm ¼ W 5% |
| R2 | 1k5 ¼ W 5% |
| S1, S2, S3 | SPST toggle switch |