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PHYSICS

Paper 1

Assessment, 2025

Discussion



ALLIANCE JOINT EXAMINATIONS BOARD (AJEB)

Uganda Certificate of Certificate

PHYSICS

Paper One

Digital Electronics Assessment

INSTRUCTIONS TO CANDIDATES:

Discussion all items well

Clearly show the working and use illustrations where necessary

Scenario One: Understanding Digital Electronics in Everyday Life

You are a student in a Ugandan lower secondary school studying Digital Electronics. Your teacher has introduced you to the concept of potential dividers, logic gates, and how digital circuits process binary information. These concepts are not just theoretical, they are used in everyday devices like radios, calculators, and smartphones.

To deepen your understanding, your teacher has assigned group research tasks and presentations. You will explore how resistors create potential dividers, how logic gates form control circuits, and how binary information is stored and processed in digital instruments.

Tasks for the Learner

Task 1: Potential Dividers in Real-Life Applications

- Explain how a potential divider works using resistors of different values.
- Draw a simple circuit diagram showing how a volume control on a radio act as a potential divider.
- Measure and record the potential difference at different points in a given resistor divider circuit.

Task 2: Logic Gates and Truth Tables

- Construct truth tables for the following logic gates: AND, NAND, OR, and NOR.
- Using a logic gate simulator (or drawn diagrams), demonstrate how two NOR gates can form a bistable switch.
- Explain how bistable switches can be used in a binary counting circuit.

Task 3: Digital Circuits and Binary Processing

- Describe how logic circuits store and process binary information.
- Give two examples of digital instruments that use binary data and explain their importance in daily life.

Task 4: Research and Presentation

- In groups, research and prepare a 5-minute presentation on:

- The role of resistors in digital control circuits.
- How logic gates are combined to create memory storage (e.g., flip-flops).
- The advantages of digital instruments over analog ones.

Scenario Two: Designing a Simple Security System Using Digital Electronics

You are part of a team of young engineers in Uganda tasked with designing a basic security system for a school laboratory. The system will use digital electronics concepts such as potential dividers, logic gates, and bistable switches to detect unauthorized entry and trigger an alarm.

Your team must research and apply principles of digital circuits to create a functional prototype. The system should include:

- A ***potential divider circuit*** to sense changes in light or resistance (simulating a door sensor).
- ***Logic gates (AND, OR, NOT, etc.)*** to process input signals and activate an alarm.
- A ***bistable switch (flip-flop)*** to keep the alarm triggered even if the sensor is no longer active.

Tasks for the Learner

Task 1: *Designing the Sensor Circuit*

- Sketch a potential divider circuit using an LDR (Light Dependent Resistor) that produces a voltage drop when light is blocked (simulating a door opening).
- Calculate the output voltage for two different resistor values (e.g., $1\text{k}\Omega$ and $10\text{k}\Omega$) when the LDR resistance changes.

Task 2: *Logic Gate Control System*

- Construct a truth table for an **OR gate** and an **AND gate** to decide when the alarm should trigger (e.g., if either of two sensors is activated OR both must be activated for security).

- Draw a circuit diagram showing how these logic gates process signals from the potential divider.

Task 3: *Memory Circuit for Alarm Latching*

- Explain how a **bistable switch (flip-flop)** made from NOR gates can keep the alarm activated even after the sensor resets.
- Design a simple latch circuit using two NOR gates and describe how it holds the alarm state.

Task 4: *Real-World Application Report*

- Research and write a short report (1 page) on:
 - How digital security systems are used in homes/banks in Uganda.
 - Why binary logic is more reliable than manual switches in such systems.
 - One limitation of your proposed design and how it could be improved.

Scenario Three: *Smart Streetlight Control System Using LDRs and Logic Gates*

Your town council wants to automate streetlights to save energy. The system must: Use **Light Dependent Resistors (LDRs)** to detect daylight, Activate lights only when it's dark **AND** when motion is detected (to avoid wasting power) and Include a **bistable latch** to keep lights on for 2 minutes after motion stops.

Tasks for the Learner

Task 1: *Potential Divider Calculations for LDR Sensing*

- An LDR has a resistance of **500Ω in daylight** and **10kΩ in darkness**.
- Design a potential divider with a **fixed 4.7kΩ resistor** connected to a **5V supply**.
 - Calculate the output voltage (V_{out}) in **daylight** and **darkness**.
 - Determine if this voltage can trigger a logic gate (assume TTL logic needs **>2V for HIGH**).

Task 2: *Logic Gate System for Motion-Activated Lighting*

- The system uses:

- **AND gate:** Lights turn on **only if** (Dark = HIGH **AND** Motion = HIGH).
 - **OR gate:** Override switch (manual ON if either Dark **OR** Motion is HIGH).
- Construct truth tables for both cases.
- Explain which design is more energy-efficient.

Task 3: *Bistable Latch Timer Circuit*

- A **555 monostable circuit** holds the lights on for 2 minutes after motion stops.

Task 4: *Real-World Optimization Report*

- Research:
 - Why Uganda's streetlights should use **digital control** instead of manual switches.
 - How adding a **NAND gate** could make the system fail-safe (e.g., lights stay on if LDR fails).

Scenario Four: Digital Water Level Indicator for Rainwater Harvesting

A school's rainwater tank needs a **3-level indicator** (Empty/Half/Full) using:

- **Float switches** (resistive sensors) as inputs.
- **Logic gates** to display status on LEDs.
- **Transistor drivers** to power LEDs brightly.

Tasks for the Learner

Task 1: *Potential Divider Design for Float Sensors*

- Three float switches output:
 - **Empty = 0V, Half = 2.5V, Full = 5V.**
- Design a comparator circuit using **resistors** to convert these voltages into binary (00/01/10).

Task 2: *Logic Circuit for LED Indicators*

- Truth table:

Empty (A)	Half (B)	Full (C)	Red LED	Yellow LED	Green LED
0	0	0	ON	OFF	OFF
0	1	0	OFF	ON	OFF
0	0	1	OFF	OFF	ON

- Derive the Boolean expressions for each LED

Task 3: *Cost-Benefit Analysis*

- Compare this digital system to an **analog voltmeter display**.
- List **2 advantages** (e.g., accuracy) and **1 disadvantage** (e.g., complexity).

Scenario One: Understanding Digital Electronics in Everyday Life

Task 1: Potential Dividers in Real-Life Applications

Explanation

A potential divider is a simple circuit that uses two resistors in series to produce a voltage that is a fraction of the input voltage. The output voltage depends on the ratio of the two resistor values.

Formula:

$$V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}$$

Circuit Diagram: Volume Control (Radio)

+Vcc (e.g., 9V)

|

[R1]

|-----V_{out} (to amplifier)

[R2]

|

GND

Where R1 and R2 are adjustable (e.g., variable resistors or potentiometers) to control volume.

Measurement

Use a multimeter to measure voltages at different points:

- Measure across R1 and R2
- Change resistance values and record V_{out}

Task 2: Logic Gates and Truth Tables

Truth Tables

A	B	AND	NAND	OR	NOR
0	0	0	1	0	1
0	1	0	1	1	0
1	0	0	1	1	0
1	1	1	0	1	0

Bistable Switch with NOR Gates

- Two cross-coupled NOR gates can form an SR flip-flop.

Diagram

Application:

Bistable switches (flip-flops) store 1-bit of data. Used in:

- Counters
- Memory units in digital watches or calculators

Task 3: Digital Circuits and Binary Processing

Explanation

Logic circuits use combinations of gates to store and process 0s and 1s. Memory elements like latches and flip-flops store state information.

Examples:

1. **Calculator** – stores digits in binary format
2. **Digital clock** – uses binary counters to keep track of time

Task 4: Research and Presentation

- **Role of Resistors:** Control current, divide voltages, pull-up/down signals.
- **Memory Storage:** Flip-flops made from NOR/NAND gates retain data.
- **Advantages of Digital Instruments:**

- Greater accuracy
- Easy to replicate signals
- Lower noise interference

Scenario Two: Security System Design

Task 1: Sensor Circuit with LDR

LDR-Based Potential Divider Diagram

5V --- [LDR] --- Vout --- [Fixed R] --- GND

Calculations:

Let $V_{in} = 5V$

Case 1: LDR = $1k\Omega$, R = $10k\Omega$

$$V_{out} = 5 \times \frac{10k}{1k + 10k} \approx 4.55V$$

Case 2: LDR = $10k\Omega$, R = $1k\Omega$

$$V_{out} = 5 \times \frac{1k}{10k + 1k} \approx 0.45V$$

Task 2: Logic Gate Control System

Truth Tables

- **OR Gate** (Either sensor triggers alarm)

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

- **AND Gate** (Both sensors must trigger)

A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

Logic Circuit Diagram

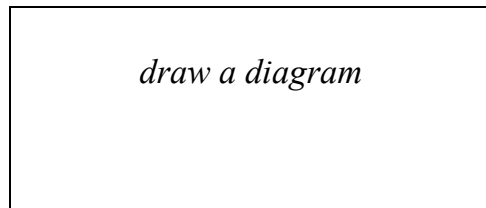
Sensor A ---\

[OR gate] ----- Alarm

Sensor B ---/

Task 3: Memory Circuit for Alarm Latching

NOR Flip-Flop Diagram



Explanation:

Even if the input goes LOW, output Q remains HIGH until reset.

Task 4: Real-World Report (Summary)

- **Use in Homes/Banks:** Intrusion detection, fire alarms.
- **Binary vs Manual Switches:** Digital logic enables automation and accuracy.
- **Limitation:** Power-dependent; needs backup supply.
Improvement: Add rechargeable battery backup.

Scenario Three: Smart Streetlight Control

Task 1: LDR Divider Calculations

Daylight:

LDR = 500Ω , R = $4.7k\Omega$

$$V_{out} = 5 \times \frac{4.7k}{4.7k + 500} \approx 4.26V$$

Darkness:

LDR = $10k\Omega$

$$V_{out} = 5 \times \frac{4.7k}{10k + 4.7k} \approx 1.60V$$

Triggering Logic:

TTL logic needs $>2V$ = **HIGH**

- **Daylight** → **HIGH**
- **Darkness** → **LOW** (Not **HIGH** – can be inverted using **NOT** gate)

Task 2: Logic for Motion-Activated Lighting

AND Gate:

Dark	Motion	Output
0	0	0
0	1	0
1	0	0
1	1	1

OR Gate (Manual Override):

Dark	Motion	Output
0	0	0
0	1	1
1	0	1
1	1	1

More Efficient:

AND gate saves energy — lights only when needed.

Task 3: 555 Monostable Circuit

- **Use:** Keeps output HIGH for fixed time (e.g., 2 minutes)
- **Circuit:**
 - Triggered by motion sensor
 - Lights stay ON even after motion stops

Task 4: Optimization Report (Summary)

- **Why Digital in Uganda:** Saves energy, reduces manual work
- **NAND for Fail-Safe:** If LDR fails (stuck at HIGH), NAND ensures override logic keeps lights ON
- **Improvement:** Add timer and battery backup

Scenario Four: Digital Water Level Indicator

Task 1: Float Switch Comparator

Levels:

Level	Voltage	Binary
Empty	0V	00
Half	2.5V	01
Full	5V	10

- Use voltage comparators (e.g., LM339) to detect thresholds and convert to binary.

Task 2: LED Indicator Logic

Truth Table Given:

A	B	C	Red	Yellow	Green
0	0	0	1	0	0
0	1	0	0	1	0
0	0	1	0	0	1

Boolean Expressions:

- Red LED: $A' \cdot B' \cdot C'$
- Yellow LED: $A' \cdot B \cdot C'$
- Green LED: $A' \cdot B' \cdot C$

Task 3: Cost-Benefit

Advantages of Digital:

1. Accurate and clear LED display
2. Easily integrated with alarms

Disadvantage:

- Requires more components and circuit design knowledge