



University of Fort Hare
Together in Excellence

PHY 516: SPECIAL TOPICS IN PHYSICS

BACHELOR OF SCIENCE HONOURS DEGREE IN PHYSICS EXAMINATION

YEAR: MAY/JUNE 2023

DURATION: 3 HOURS

MARKS: 100

THIS PAPER CONSISTS OF **FOUR** PAGES INCLUDING THE COVER PAGE

INTERNAL EXAMINER

Dr. P. MUKUMBA
[University of Fort Hare]

EXTERNAL EXAMINER

Dr. Z. CHIGUVARE
[University of Namibia]

INSTRUCTION FOR CANDIDATES

ANSWER ALL QUESTIONS

QUESTION 1 [25 marks]

- 1.1. The principle of operation of a solar cell is based on the photovoltaic effect. What is the photovoltaic effect, and which are the fundamental processes behind this effect? [5]
- 1.2. Explain the fundamental differences between the operational principles of the crystalline silicon and the amorphous silicon solar cells. [2]
- 1.3. With the aid of diagrams, explain differences between the structures of single-junction amorphous silicon solar cell and the crystalline silicon solar cells. [10]
- 1.4. Name four major efficiency losses in a crystalline silicon solar cell? Explain them briefly. [5]
- 1.,5. Explain the approaches to make the solar cells more efficient by minimizing the optical losses.[3]
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QUESTION 2 [25 marks]

- 2.1. Calculate solar cell temperature, T_{cell} , when given the following: [4]
Ambient air temperature, $T_{air} = 20^{\circ}\text{C}$; Cell temperature at NOCT = 50°C ;
Insolation level, $S = 80 \text{ mW/cm}^2$.
- 2.2. A house has the following electrical appliance usage.
- Four 40 W electric bulbs used 5 hours per day.
 - One 60 W fan used for 2 hours per day.
 - One 60 W television used for 4 hours per day
 - One 50 W radio used for 5 hours per day.
 - One 100 W refrigerator that runs 24 hours per day.

The system will be powered by 12 Vdc batteries (160 Ah) and 200 Wp PV modules.

Determine:

- 2.2.1. Power consumption demands [5]
- 2.2.2. Size of the PV panel [4]
- 2.2.3. The size of the battery bank (amp-hours) when:
- Deep Cycle Batteries are used; and [4]
 - Shallow Cycle Batteries are used. [4]
- 2.2.4. The size of the Inverter [4]

Assumptions:

Sunshine hours = 5
Days of autonomy = 3
DOD for deep cycle batteries = 80%
DOD for shallow cycle batteries = 20%
Inverter safety = 25%
Charging efficiency = 90%

QUESTIONS 3 [25 marks]

3.1. The wind speed in a fully grown maize field at a height of 2m from the ground is 4ms^{-1} . Estimate the wind speed at a height of 20 m. The friction co-efficient, $\alpha = 0.20$. [5]

3.2. Show that the **power in wind** is given by:

$$P_w = \frac{1}{2} \rho A V^3, \text{ where symbols have their usual meaning.} \quad [5]$$

3.3. State 3 basic principles in fluid dynamics used to analyse the performance of wind turbine in an Actuator Disk Theory. [3]

3.4. Show that **Thrust, T**, is given by:

$$T = \frac{1}{2} \rho A v_o^2 .4a(1 - a), \text{ hence prove that the Lanchester-Betz limit} = 0.593. \quad [12]$$

QUESTIONS 4 [25 MARKS]

A farm has 50 head of stabled milk cows, 50 head of pastured cattle, 100 head of pastured goats and 100 caged chickens. The farmer wants to construct a biogas digester and intends to use the gas for cooking, domestic lighting, an incubator, a colour television and a refrigerator. The farm is doing well that there is a chance to expand the dairy production.

4.1. Calculate the expected daily biogas yield. [10]

4.2. Calculate the digester volume. [10]

4.3. Name **two** biogas digester types that are common in South Africa. What are the advantages of the mentioned digesters? [5]

Note: For your calculations use data on **Table 1**.

Table 1: Parameters for the substrates and Biogas consumption

CATTLE MANURE	
Average live weight of animal[kg]	400
Excrement yield as % of live weight	5
Total solids content %	16
Volatile solids content %	13
Mixing ratio	1:1
Gas yield / kg volatile solids [liters]	250
Retention time	25 days
GOAT MANURE	
Average live weight of animal[Kg]	50
Excrement yield as % of live weight	3
Total solids content %	30
Volatile solids content %	20
Mixing ratio	1:3
Gas yield / kg volatile solids [liters]	200
Retention time	30 days
CHICKEN MANURE	
Average live weight of animal[kg]	1.5
Excrement yield as % of live weight	4.5
Total solids content %	25
Volatile solids content %	17
Mixing ratio	1:5
Gas yield / kg volatile solids [liters]	460
Retention time	30 days
HUMAN EXCRETA	
Average live weight of animal[kg]	60
Excrement yield as % of live weight	1
Total solids content %	20
Volatile solids content %	15
Mixing ratio	-
Gas yield / kg volatile solids [liters]	300
Retention time	21 days
Biogas consumption m³/h	
Biogas cooker	0.2
Gas lamp	0.1
incubator	1
Electric rating [w]	
Incandescent light	60
Fluorescent light	20
Colour TV	60
Radio	10
Refrigerator	120; assume 1kWh/d

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