



KISII UNIVERSITY

UNIVERSITY EXAMINATIONS

SECOND YEAR EXAMINATION FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE RENEWABLE ENERGY

SECOND SEMESTER 2022/2023

(JUNE - SEPTEMBER, 2022)

PHRE 222: THERMOCHEMICAL CONVERSION OF BIOMASS

STREAM: Y2 S2

TIME: 2 HOURS

DAY: THURSDAY, 3:00 PM – 5:00 PM

DATE: 08/09/2022

INSTRUCTIONS

- 1. Do not write anything on this question paper.**
- 2. Answer Question ONE (compulsory) and any other TWO questions.**
- 3. Use the following constants where necessary;**

Specific heat of dry wood, $c_{pdf} = 1000 \text{ J/kgK}$,

Specific heat of water, $c_{pwc} = 4180 \text{ J/kgK}$.

Heat of vaporisation, is 2400 kJ/kg

Emissivity of wood, $\varepsilon = 0.90$

$$k_{rv0} = 1.9 \times 10^{12} \text{ s}^{-1}$$

$E / \mathcal{R} = 21500 \text{ K}$.

Convective heat transfer coefficient, $k_{cg} = 0.0625$

Stefan-Boltz constant, $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$.

QUESTION ONE

- What do you understand by the following terms; [4marks]
 - Biochar
 - Bio-oil
 - Syngas
 - Pyrolysis
- State two components of biomass. [2marks]

- c. Biochar has many applications in real life situations. State any three of them. [3marks]
- d. State and explain the two forms in which moisture in solid fuels can exist. [4marks]
- e. Biomass is classified into two main categories. Name them. [2marks]
- f. State any two advantages and two disadvantages of Fixed bed Up draft gasifiers. [4marks]
- g. State the three factors that a number of volatile products and their composition depends on. [3marks]
- h. What are the three things that the design of a gasifier depends on? [3marks]
- i. State any two gasfying agents which are used during the gasification process. [2marks]
- j. State any three disadvantages of bubbling fluidized bed reactor. [3marks]

QUESTION TWO

- a. Discuss how the following parameters affects gasification; [12marks]
 - i. Superficial velocity
 - ii. Biomass Characteristics
 - iii. Moisture content
 - iv. Gasifying agent
 - v. Catalyst
 - vi. Operating temperature.
- b. "Combustion systems can work with relatively high amounts of tar but hydrocarbon conversion catalysts and fuel cells need syngas with low levels of tar." In reference to this statement, explain how syngas is cleaned using the following subheadings; [8marks]
 - i. Particulate removal
 - ii. Alkali removals
 - iii. Nitrogen compounds
 - iv. Sulphur compounds

QUESTION THREE

- a. Briefly discuss the four discrete thermal processes that are involved in the Gasification process. [12marks]
- b. Explain the following tar removing techniques; [8marks]
 - i. In bed catalyst
 - ii. Wet cleaning

QUESTION FOUR

- a. A $100 - \mu\text{m}$ oak particle which contains 40% moisture (dry basis) is injected into a $1500 - \text{K}$ furnace. The oak particle was initially at 300 K and had a dry density of 690 kg/m^3 . Find the drying time. [8marks]
- b. The oak particle in (a) above is devolatilised in the same surrounding (1500 K). Compare the time needed for heating of the particle with the time to release 99% of the volatile mass due to the kinetic rate. [5marks]
- c. Write an overall reaction in an air and/ or steam gasifier. [2marks]
- d. Write any other five balanced chemical reactions that are the proceeds of the overall reaction stated in (b) above. [5marks]

QUESTION FIVE

- a. Discuss the following gasifiers; [16marks]
 - i. Cross-draft gasifier
 - ii. Fluidized bed gasifier
 - iii. Down draft gasifier
 - iv. Up-draft gasifier
- b. State the three disadvantages of wet tar cleaning technique. [3marks]
- c. What is lignin? [1mark]