BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ENGINEERING AND PHYSICS

BACHELOR OF SCIENCE HONOURS DEGREE IN ENVIRONMENTAL PHYSICS AND ENERGY SOURCES

HPH124 (3): COMPUTATIONAL PHYSICS

DURATION: 3 HOURS   TOTAL MARKS: 100   ≋ JAN 2025

INSTRUCTIONS TO CANDIDATES

Answer ALL parts of Section A using an answer booklet and any THREE questions from Section B using a Computer.

Section A carries 40 marks and each question of Section B carries 20 marks.

CONSTANTS

Symbol	Meaning	Value	
S_{input}	Solar constant	1361	Wm^{-2}
A	Albedo	0.3	
ε	Emissivity	0.6	
σ	Stefan-Boltzmann constant	5.67	$Wm^{-2}K^{-4}$
g	Gravity	9.81	Wm^{-2}
c_p	Air-specific heat capacity at constant pressure	1005	$Jkg^{-1}J^{-1}$
ρ	Air density	1.225	kgm^{-3}

SECTION A (USE ANSWER BOOKLET)

Question 1

a) Which of the following is NOT a feature provided by the Python extension in VS Code? (1)
   a. IntelliSense (code completion)
   b. Debugging tools
   c. Git version control integration
   d. Compiling Python code to C++

b) Explain the purpose of numerical differentiation and provide an example of when it might be used in environmental physics (4)

c) Describe the relationship between wind speed and power output in a wind turbine. (4)

d) (i) Discuss the factors that affect the performance of a photovoltaic system and how these can be incorporated into a Python model to improve the accuracy of energy output predictions. (6)

(ii) Provide examples from solar irradiance variation, temperature effects, and system losses. (4)

e) Describe the concept of carbon neutrality in the context of biomass energy. (4)

f) What is the main environmental concern associated with nuclear energy? (1)
   a. Greenhouse gas emissions
   b. Radioactive waste management
   c. Air pollution
   d. Soil degradation

g) (i) Discuss the environmental challenges of fossil fuels and nuclear energy. (4)
   (ii) How can Python-based simulations help assess and mitigate the environmental impact of these non-renewable energy sources? (4)

h) Explain the key challenges of integrating renewable energy sources like wind and solar into a smart grid. How can Python-based models help address these challenges? (6)

SECTION B (PRACTICAL, USE A COMPUTER)

Question 2
Write a Python script using VS Code that generates and plots a cosine wave. (20)

Question 3
Given the function

$$f(x) = e^{-x^2}$$

Write a Python script using the trapezoidal rule to approximate the integral of $f(x)$ from 0 to 1. What is the numerical value of the integral? (20)

Question 4
Model the charge and discharge cycle of a battery over time.

Question 5
Write a Python script using Matplotlib to plot a heatmap of random temperature data over a 15x15 grid. (20)

Question 6
a) Write a Python script to simulate the integration of wind energy into a smart grid. Assume wind energy generation follows a sine wave pattern over 24 hours, with a peak generation of 1,500 kW at 12 hours. The energy demand follows a constant rate of 1,000 kW per hour. (15)
b) Calculate how much energy needs to be drawn from the grid. (5)

END OF PAPER