

**RAN-2403080103044003**
**M.Sc. (Sem. III) Examination October - 2025**
**Physics**
**PH-534 : Elective-3: Python Programming and Computational Physics**
**Time: 03 Hours ]**
**[ Total Marks: 70**
**સૂચના : / Instructions**

- (1) ઉપરોક્ત દર્શાવેલ વિગતો ઉત્તરવહી પર અવશ્ય લખવી.  
Fill up strictly the above details on your answer book
- (2) Symbols used have their usual meaning.
- (3) Figures to the right indicate full marks.

Seat No.:

     

Student's Signature

**Q-1.**
**Attempt any two questions out of the (a), (b) and (c) below.**

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|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| (a) | (i) What is slicing in the context of Python lists? Provide an example where slicing is used to extract a subset of elements from a list.                                                                                                                                                         | <b>05</b> |
|     | (ii) Explain the different functions for creating arrays (1-d).                                                                                                                                                                                                                                   | <b>04</b> |
| (b) | (i) Describe the process of importing and using Python modules with examples. What are the differences between importing an entire module and importing specific functions from a module?                                                                                                         | <b>05</b> |
|     | (ii) What is a high level language? Explain the key differences between a compiler and an interpreter.                                                                                                                                                                                            | <b>04</b> |
| (c) | (i) What is the output of the following code?<br><pre> str1="hello students welcome to CLASS" print(str1) print(str1[15]) print(str1[-20]) print(str1[2:16]) print(str1[-10:-4]) print(str1[2:16:3]) print(str1[-15:-3:3]) print(str1[:]) print(str1[:20]) print(str1[::5]) </pre>                | <b>05</b> |
|     | (ii) Write a Python script to compute the height and velocity of a ball thrown from an initial height of 1.6 meters with an initial velocity of 14.2 m/s after 0.5 seconds and 2.0 seconds. Assume the acceleration due to gravity is $9.81 \text{ m/s}^2$ . Write down the output of the script. | <b>04</b> |

**Q-2.**
**Attempt any two questions out of the (a), (b) and (c) below.**

- |     |                                                                                                                                                                                                                             |           |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| (a) | (i) Write a Python script that calculates all the Fibonacci numbers smaller than 400. The script should utilize a while loop to generate the sequence and store the results in a list. Write down the output of the script. | <b>05</b> |
|     | (ii) Explain the difference between the assignment operator (=) and the equality operator (==) in Python. Provide an example to illustrate your answer.                                                                     | <b>04</b> |

- (b) (i) Write a Python script to plot the function  $y = \frac{\cos x}{1 + \frac{1}{5}x^2}$  for  $-15 \leq x \leq 15$ . **05**  
Your script should include appropriate axis labels, title, grid lines and enough points to create a smooth curve.
- (ii) What is a masked array in NumPy and how can it be useful in plotting? **04**  
Write a Python code that demonstrates how to use a masked array to exclude specific data points from a plot.
- (c) (i) Write a Python function that calculates the total mechanical energy of a simple harmonic oscillator. The function should take two parameters: the spring constant (in N/m) and the amplitude (in meters). Write down the expected output of your function. **05**
- (ii) Explain the difference between positional and keyword arguments in Python functions. How does the order of these arguments affect a function call? **04**

**Q-3. Attempt any two questions out of the (a), (b) and (c) below.**

- (a) (i) Write a Python script to plot the potential energy based on even powers of displacement for a harmonic oscillator (with  $p=2$ ) and an harmonic oscillator (with  $p=6$ ) over displacement values ranging from -2 to 2. Ensure the plot includes grid lines, axis labels, a title, and a legend. Give tentative output of your script. **05**
- (ii) What are free nonlinear oscillations, and how do they differ from linear oscillations? Write down the equation of motion for a mass attached to a spring with a nonlinear restoring force. Explain each term in the equation. **04**
- (b) (i) Write a Python script to simulate population dynamics using the logistic map. Take into consideration 100 generations, growth parameters 3.5 and 3.8, with an initial population of 0.1. The script should generate the plots of population over generations for both value of growth parameters. Ensure that the plots includes labeled axes and a clear title for effective visualization. **05**
- (ii) Derive the equation of motion for a chaotic pendulum, considering gravitational torque, friction, and an external driving torque. Also, convert the second-order differential equation into first-order equations. **04**
- (c) (i) Derive the equations governing the Lotka-Volterra model for both prey and predators. Clearly indicate the parameters involved and their biological significance. **05**
- (ii) A nonlinear population follows the logistic growth model. The growth parameter is 3.2 and the initial population fraction is 0.4. (a) Calculate the population after the first step. (b) Using that result, calculate the population after the second step. (c) Comment on whether the population is moving toward stability or showing variation. (d) What happens to the population in the logistic growth model if the growth parameter is too high (e.g., greater than 3.5)? **04**

**Q-4. Attempt any two questions out of the (a), (b) and (c) below.**

- (a) (i) Write a Python script to simulate a Gaussian wave packet. The script should generate three plots for the (1) real part, (2) imaginary part, and (3) probability density. All plots are clearly labeled with titles, axes labels, legends, and grid lines. **04**
- (ii) Derive the time-dependent Schrodinger equation for a one-dimensional particle. Discuss the physical significance of each term in the equation. **04**

- (b) (i) Write down the relevant Maxwell's equations for an electromagnetic wave propagating along the z-axis. Discuss how these equations describe the interaction of the electric and magnetic fields as they pass through the wave plate. **04**
- (ii) A linearly polarized plane electromagnetic wave in vacuum has a magnetic-field component along the y-direction given by **04**
- $$H_y(z, t) = H_0 \sin(kz - \omega t)$$
- Where magnetic amplitude is 1.00 A/m, wave number is  $2.00 \text{ m}^{-1}$  and angular frequency is  $6.0 \times 10^8 \text{ S}^{-1}$ . Use the vacuum permittivity  $8.854 \times 10^{-12} \text{ F/m}$ . Evaluate the time derivative of the electric field at position 0.50 m and time  $1.0 \times 10^{-9} \text{ s}$ . Give your answer with units and state whether the time derivative of the electric field is positive or negative.
- (c) (i) In wave packet scattering, what is the normalization condition for the two particle wave function and also explain why the total wave function for identical particles be either symmetric or antisymmetric. **04**
- (ii) Explain the importance of the relative phase shift between the electric field components  $E_x$  and  $E_y$  after passing through the wave plate. How does this phase shift facilitate the transformation from linear to circular polarization? **04**
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