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UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2017

Program: Nuclear Science & Technology
Subject (Course): Computer Programming & Simulations
Course Code : NSAT7007
No. of page/s: 04

Semester – I
Max. Marks : 100
Duration : 3 Hrs

Section A (5 × 4 = 20 marks)
All questions are compulsory

Q1: Define encapsulation in object oriented C++. Discuss its significance. What are abstract classes? [5]

Q2: State the underlying concepts behind *modular programming*. Illustrate this by writing a program (in FORTRAN 77 or 90) which swaps two numbers entered by the user through the keyboard only if they are both even. If one of the numbers is not even, print a message that *swapping is not allowed*. [5]

Q3: Differentiate between a class and structure in C++. How the accessibility of different components of a class is controlled outside the class. [5]

Q4: Explain inheritance in object oriented C++. Which members a derived class may inherit from the base class? Which members in the base class cannot be inherited by the derived class and why?

[5]

Section B (10 × 4 = 40 marks)
Q5-Q7 are compulsory
Attempt only one question out of Q8A and Q8B

Q5: Apply Runge-Kutta of order 4 (RK4) method to numerically solve the following ODE:

$$\frac{dy}{dt} = y - t^2 + 1 \quad 0 \leq t \leq 2 \quad y(t=0) = 0.5$$

Also write a pseudocode (independent of the programming language) for the above problem. [10]

Q6: Write a program in FORTRAN 77 to perform following integration:

$$\int_3^5 \frac{dx}{\sqrt{(x^2 - 4)}}$$

Take $n=4$, and use Composite Simpson rule to perform the integration. Compare the result with the analytical value. The program should be modular. [10]

Q7: Suppose we have a base class and a derived class containing default constructors. Now if we create instances of derived class, which constructor will be called first: base class's constructor or derived class's constructor. Write a program which should print a message telling which constructor is called. What would happen if the base class has a constructor with arguments? Explain this by writing a program in which you have a *Polygon* base class with width and height as members; it also has a constructor to initialize the width and height. Derived class is a *Triangle*, which has base as data; it has a constructor to initialize the base; it also has a member function to calculate the area, which is $\frac{1}{2} \text{base} \times \text{height}$. [10]

Q8A: Write a program in FORTRAN 90 that performs Newton-Raphson algorithm for finding the roots of an equation $f(x)=0$. Apply this algorithm to

$$f(x) = e^{2x} - 5x - 1$$

[10]

Newton Raphson Method:

This method is used to find the roots of an equation $f(x)=0$. The program starts with a guess, say x_0 . If $f(x_0) < \epsilon$, where ϵ is a small number, say, 10^{-6} , x_0 is the root. If not, a tangent is drawn from $(x_0, f(x_0))$ to the function $f(x)=0$. Let us suppose this tangent intersects the x -axis at, say x_1 , which is given as

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}$$

If $f(x_1) < \epsilon$, x_1 is the root. Otherwise, another tangent from $(x_1, f(x_1))$ is drawn at $f(x)=0$ and this process continues until the condition $f(x_{n+1}) < \epsilon$ is satisfied, where x_{n+1} is

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

You should first write a subroutine to implement Newton Raphson method, and then call this routine in the main program. The data should be supplied from the main program.

OR

Q8B: A wind tunnel is a test chamber built to generate different wind speeds, or Mach numbers (which is the wind speed divided by the speed of sound). Accurate scale models of aircraft can be mounted on force-measuring supports in the test chamber, and then measurements of the forces on the model can be made at many different wind speeds and angles. At the end of an extended wind tunnel test, many sets of data have been collected and can be used to determine the coefficient of lift, drag, and other aerodynamic performance characteristics of the new aircraft at its various operational speeds and positions. Data collected from a wind tunnel test are listed in the following table:

Flight path angle (degrees)	Coefficient of lift
0	0.097
2	0.238
4	0.421
6	0.479
8	0.654

10	0.792
12	0.924

Using linear interpolation, determine the coefficient of lift for path 9 and 11 degrees flight path angles. Use FORTRAN 90 to write the code. Write modular program using only subroutines. [10]

Section C (20 × 2 = 40 marks)

Question 9 is compulsory

Attempt only one question out of Q10A and Q10B

Q9: The temperature $u(x, t)$ of a long, thin rod of constant cross section and homogeneous conducting material is governed by the 1D heat equation. If heat is generated in the material, for example, by resistance to current or nuclear reaction, the heat equation becomes

$$\frac{\partial^2 u}{\partial x^2} + \frac{Kr}{\rho C} = K \frac{\partial u}{\partial t}, 0 < x < l, 0 < t$$

where l is the length, ρ is the density, C is the specific heat, and K is the thermal diffusivity of the rod. The function $r = r(x, t, u)$ represents the heat generated per unit volume. Suppose that

$$l = 1.5 \text{ cm}, K = 1.04 \text{ cal sec}^{-1} \text{ cm}^{-1} \text{ deg}^{-1}, \rho = 10.6 \frac{\text{gm}}{\text{cm}^3}, C = 0.056 \text{ cal gm}^{-1} \text{ deg}^{-1}$$

and

$$r(x, t, u) = 5.0 \frac{\text{cal}}{\text{cm}^3} \text{ s}^{-1}$$

If the ends of the rod are kept at 0°C , then

$$u(x=0, t) = u(x=l, t) = 0, t > 0$$

Suppose the initial temperature distribution is given by

$$u(x, t=0) = \sin \frac{\pi x}{l}, 0 \leq x \leq l$$

Explain how you will solve the above model by approximating the differential operators using centered difference scheme and explicit Euler for integrating the resulting equation in time. Write a code in FORTRAN90/C++ to solve the PDE by assuming time and spatial steps. [20]

Q10A: What do you mean by operator overloading? Explain in the context of object oriented programming paradigm.

Write a class Sale which has private data members corresponding to receipt number, amount of sale and name of the salesperson. The member functions should include the constructor(s) and function(s) to



display various details. Now overload + operator to calculate the total value of the sales happened throughout the day. Test your program on at least three to four items sold during the day. [20]

OR

Q10B: What do you mean by inheritance in object oriented programming? Explain in brief, how multiple inheritance may be useful in software development using object oriented paradigm?

Create a Painting class that holds the painting title, artist name, and value. All Paintings are valued at \$400 unless they are FamousPaintings. Include a display function that displays all fields. The FamousPainting subclass overrides the Painting value and sets each Painting's value to \$25,000. Write a main() function that declares an array of 10 Painting objects. Prompt the user to enter the title and artist for each of the 10 Paintings. Consider the Painting to be a FamousPainting if the artist is one of the following: Degas, Monet, Picasso, or Rembrandt. Display the 10 Paintings. [20]





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Section A (5 × 4 = 20 marks)

All questions are compulsory

Q1: Explain abstract class. How abstract classes may be useful in object oriented software development? [5]

Q2: Q1: List various limitations in FORTRAN 77 programming. How these limitations are taken care of in FORTRAN 90? [5]

Q3: Differentiate between *cycle* and *exit* statements in FORTRAN 77 & 90. Using *cycle* & *exit*, write a program to display the following:

- Numbers from 10 to 5 and then print out a message that “*from 4 to 1 not needed! Leave It*”.
- 10, 9, 8, 7, 4, 3, 2, 1 “Run! Fire is broke in the Jungle” [5]

Q4: What is “dynamic allocation” of memory and how it is different from static allocation? What may be the consequences of not deallocating the memory allocated dynamically? Write a program in FORTRAN 90 to create a 2D array of real numbers through dynamic allocation and print the contents of that array. Use separate functions/subroutines for each task. [5]

Section B (10 × 4 = 40 marks)

Q5-Q7 are compulsory

Attempt only one question out of Q8A and Q8B

Q5: Use Euler’s scheme to approximate the solution of following ordinary differential equations in time:

$$\frac{dy}{dt} = te^{3t} - 2y \quad 0 \leq t \leq 1, \quad y(t=0) = 0, \quad h = 0.2$$

Discuss how the error ($|y(t_i) - y_i|$, where $y(t_i)$ is analytical solution and y_i is approximated solution after $t_i = i * h$ time) varies with time by plotting it w. r. t time (prepare a rough plot in the answer sheet; no need to use graph paper). (Hint: The above ODE is 1st order non-homogeneous, whose analytical solution is: $y(t) = \frac{1}{e^{2t}} \int t e^{5t} + \frac{c}{e^{2t}}$, where c is constant of integration which can be found by using initial condition given above.). Write a code in FORTRAN 90 to explain how you would solve this problem computationally). [10]

Q6: A particle of mass m moving through a fluid is subjected to a viscous resistance R , which is a function of the velocity v . The relationship between the resistance R , velocity v , and time t is given by the equation:

$$t = \int_{v(t_0)}^{v(t)} \frac{m}{R(u)} du$$

Suppose $R(v) = -v\sqrt{v}$ for a particular fluid, where R is in Newtons and v is in m/s. If $m = 10$ kg, $v(t_0) = 10$ m/s (initial velocity), approximate the time required for the particle to slow down to $v(t) = 5$ m/s. [10]

Q7: A CollegeCourse class includes fields representing department, course number, credit hours, and tuition. Its child, LabCourse, includes one more field that holds a lab fee charged in addition to the tuition. Create appropriate functions for these classes, and write a main() function that instantiates and uses objects of each class. [10]

Q8A: What are abstract classes in object oriented C++? Can you create instances of an abstract class? How an abstract class may be used in Polymorphism? Write a program to calculate the volume closed shapes such as cone, cylinder and sphere using the polymorphic properties of the abstract classes. [10]

OR

Q8B: Design a SoccerPlayer class that includes three integer fields: a player's jersey number, number of goals, and number of assists. Include an operator >() function for the class. One SoccerPlayer is considered greater than another if the sum of goals plus assists is greater. Create an array of 11 SoccerPlayers, then use the > operator to find the player who has the greatest total of goals plus assists. [10]

Section C (20 × 2 = 40 marks)

Question 9 is compulsory

Attempt only one question out of Q10A and Q10B

Q9: A car laps a race track in 84 seconds. The speed of the car at each 6-second interval is determined by using a radar gun and it given from the beginning of the lap, in feet/second, by the entries in the following table.

Time	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84
Speed	124	134	148	156	147	133	121	109	99	85	78	89	104	116	123

How long is the track? Use Trapezoidal rule to find the length of the track. The composite formula for Trapezoidal rule is:

$$\int_a^b f(x)dx \approx \frac{h}{2} \left[f(a) + 2 \sum_{j=1}^{n-1} f(x_j) + f(b) \right]$$

[20]

Q10A: Solve the following mass transport equation

$$\frac{\partial C}{\partial t} = D \left(\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial y^2} \right)$$

By performing implicit time integration in time and centered difference approximation for spatial differential operators. In the above equation, C is the concentration and D (take $D=1$) is the diffusivity of the species. The PDE has to be numerically solved on a rectangular domain with dimensions 10×10 (arbitrary units with boundary and initial conditions as given below:

$$C(x=0, y, t) = C(x=l_x, y, t) = C_1$$

$$C(x, y=0, t) = C(x, y=l_y, t) = C_2$$

$$C(x, y, t=0) = C_0$$

You may take the time and spatial steps of your choice. Consider 4 nodes along x and y (which will include the boundary nodes also). (**Hint:** Discretize the equation and write the system of discretized equations in the form of $Ax=b$, and discuss how you will solve it. Pseudo code will be sufficient). [20]

OR

Q10B: To simulate the thermal characteristics of disk brakes (see the figure below), D.A. Secrist and R.W. Hornbeck needed to approximate numerically the "area averaged lining temperature," T , of the brake pad from the equation

$$T = \frac{\int_{r_e}^{r_o} T(r) r \theta_p dr}{\int_{r_e}^{r_o} r \theta_p dr}$$

where r_e and r_o represent the radius at which the pad-disk contact begins and outside radius of the pad-disk contact, respectively; θ_p represents the angle subtended by the sector brake pads, and $T(r)$ is the temperature at each point of the pad, obtained numerically from analyzing the heat equation. Suppose

$r_e=0.308$ ft, $r_o=0.478$ ft, $\theta_p=0.7051$ radians, and the temperatures given in the following table have been calculated at various points on the disk (along radial direction). Approximate the value of T [Hint:

Use Composite Trapezoidal rule $\int_a^b f(r) dr \approx \frac{h}{2} \left[f(a) + 2 \sum_{j=1}^{n-1} f(r_j) + f(b) \right]$ to perform the integration].

[20]

