Tutorial Sheet for Beginners

PHC 501/643 | COMPUTER PROGRAMMING | SPRING 2024

1. **Projectile Motion Simulation**

   Description: Simulate the motion of a projectile launched at an angle to the horizontal and calculate its position at regular time intervals using a loop.

   Formulas:

   $$x(t) = v_0 \cdot \cos(\theta) \cdot t$$
   $$y(t) = v_0 \cdot \sin(\theta) \cdot t - \frac{1}{2}gt^2$$

   Constants:

   $$v_0 = 20\,\text{m/s}$$
   $$\theta = 30^\circ$$
   $$g = 9.81\,\text{m/s}^2$$

   Inputs: $v_0 = 20$ m/s, $\theta = 30^\circ$, $g = 9.81$ m/s^2

2. **Orbit Simulator**

   Description: Simulate the orbit of a planet around a star using a loop to update the planet's position over time.

   Formula: Newton's Law of Universal Gravitation

   Constants:

   $$M = 2 \times 10^{30}\,\text{kg}$$
   $$G = 6.67430 \times 10^{-11}\,\text{m}^3/(\text{kg s}^2)$$

   Inputs: $M = 2 \times 10^{30}$ kg, $G = 6.67430 \times 10^{-11}$ m^3/(kg s^2)

3. **Temperature Conversion Table**

   Description: Generate a table of temperature conversions from Celsius to Fahrenheit and vice versa using loops.

   Formulas: Celsius to Fahrenheit ($F = \frac{9}{5}C + 32$), Fahrenheit to Celsius ($C = \frac{5}{9}(F - 32)$)

   Constants: None

   Inputs: None (generate a table for a range of temperatures)

4. **Free Fall Calculator**

   Description: Calculate the time it takes for an object to fall freely from a certain height using a loop to increment time until the object hits the ground.

   Formula: $y(t) = \frac{1}{2}gt^2$

   Constants: $g = 9.81$ m/s^2

   Inputs: $g = 9.81$ m/s^2, y (height)

5. **Wave Motion Simulation**

   Description: Simulate the motion of waves on a string and update the position of points on the string over time using a loop.

   Formula: Wave equation, e.g., $y(x,t) = A\sin(kx - \omega t)$

   Constants:

$$\begin{aligned} A &= 1 \\ \lambda &= 2\,\text{m} \\ f &= 5\,\text{Hz} \end{aligned}$$

   Inputs: $A = 1$, $\lambda = 2$ m, $f = 5$ Hz

6. **Simple Harmonic Oscillator**

   Description: Simulate the motion of a mass on a spring undergoing simple harmonic motion and calculate its position over time using a loop.

   Formula: $x(t) = A\cos(\omega t)$

   Constants:

$$\begin{aligned} A &= 0.1\,\text{m} \\ \omega &= 2\pi\,\text{rad/s} \end{aligned}$$

   Inputs: $A = 0.1$ m, $\omega = 2\pi$ rad/s

7. **Magnetic Field Calculation**

   Description: Calculate the magnetic field at different points around a current-carrying wire using loops to perform the calculations.

   Formula: Magnetic field due to a current-carrying wire ($B = \frac{\mu_0 I}{2\pi r}$)

   Constants:

$$\begin{aligned} \mu_0 &= 4\pi \times 10^{-7}\,\text{T m/A} \\ I &= 5\,\text{A} \end{aligned}$$

   Inputs: $\mu_0 = 4\pi \times 10^{-7}$ T m/A, $I = 5$ A, r (distance from wire)

8. **Optics: Snell's Law Simulation**

   Description: Simulate the behavior of light rays passing through different mediums using Snell's Law and update the path of light rays at interfaces. Use a loop to trace the path of light.

   Formulas: Snell's Law: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

   Constants: Refractive indices (n_1, n_2), angles (θ_1, θ_2)

   Inputs: $n_1 = 1.5$, $n_2 = 1.0$, initial angle (θ_1)

9. **Simple Pendulum Simulation**

   Description: Simulate the motion of a simple pendulum using the pendulum equation. Use a loop to calculate the angular displacement and position over time.

   Formulas: Pendulum equation: $\theta(t) = \theta_0 \cos\left(\sqrt{\frac{g}{L}}t\right)$

   Constants: Initial angle (θ_0), acceleration due to gravity (g), pendulum length (L)

   Inputs: $\theta_0 = 0.1$ radians, $g = 9.81$ m/s², $L = 1$ meter

10. **Gas Laws Simulator**

    Description: Simulate the behavior of an ideal gas in a container using the ideal gas law ($PV = nRT$). Use a loop to calculate pressure, volume, or temperature changes.

    Formulas: Ideal gas law: $PV = nRT$

    Constants: Gas constant (R), initial conditions (e.g., P_0, V_0, T_0)

    Inputs: $R = 8.314$ J/(mol·K), $P_0 = 100$ kPa, $V_0 = 1$ m³, $T_0 = 300$ K

11. **Charging and Discharging Capacitor**

    Description: Simulate the charging and discharging of a capacitor in an RC circuit. Use loops to calculate the charge or voltage across the capacitor over time.

    Formulas: Charging: $Q(t) = Q_{\max}\left(1 - e^{-\frac{t}{RC}}\right)$, Discharging: $Q(t) = Q_0 e^{-\frac{t}{RC}}$

    Constants: Resistance (R), Capacitance (C), initial conditions ($Q_{\max}$, Q_0)

    Inputs: $R = 1000$ ohms, $C = 0.001$ farads, $Q_{\max} = 0.001$ coulombs, $Q_0 = 0.001$ coulombs

12. **Heat Transfer in a Rod**

    Description: Simulate the heat transfer in a one-dimensional rod using the heat conduction equation. Use loops to calculate temperature changes over time.

    Formulas: Heat conduction equation: $Q = \frac{kA\Delta T}{d}$

    Constants: Thermal conductivity (k), Cross-sectional area (A), initial and boundary conditions (e.g., T_0, T_L)

    Inputs: $k = 200$ W/(m·K), $A = 0.01$ m², $T_0 = 100$ °C, $T_L = 20$ °C

13. **Atomic Decay Chain Simulation**

    Description: Simulate the decay of a radioactive element with multiple decay stages using loops. Track the populations of different isotopes over time.

    Formulas: For a decay chain involving multiple isotopes, each isotope undergoes radioactive decay according to its own decay constant (λ). The decay of an isotope follows the formula:

    $$N(t) = N_0 \cdot e^{-\lambda t}$$

    where: - $N(t)$ is the population of the isotope at time t. - N_0 is the initial population of the isotope. - λ is the decay constant for the isotope.

    Constants: Decay constants (λ) for each isotope, initial populations (N_0) of each isotope.

Sample Inputs:

$$\begin{aligned}
\text{Isotope 1 (N1):} & \\
\lambda_1 &= 0.01 \text{ per hour} \\
N_{1_0} &= 1000 \text{ particles} \\
\text{Isotope 2 (N2):} & \\
\lambda_2 &= 0.02 \text{ per hour} \\
N_{2_0} &= 500 \text{ particles} \\
\text{Time interval } (\Delta t) \text{ for simulation:} &\ 24 \text{ hours} \\
\text{Simulation time steps:} &\ 0, 1, 2, \ldots, 24 \text{ hours}
\end{aligned}$$