Sheet 1: Ant Colony Optimization

Coordinates of Points (cities):

$$x_1 = (9,\ 76),$$
$$x_2 = (28,\ 75),$$
$$x_3 = (98,\ 3),$$
$$x_4 = (69,\ 27).$$

ACO Parameters:

$$\text{Population Size} = 4,$$
$$\text{Maximum Iterations} = 10,$$
$$\text{Pheromone Evaporation Rate} = 0.05,$$
$$\text{Artificial Pheromone (Initial)} = 0.0453,$$
$$\alpha = 1, \quad \beta = 1, \quad Q = 1.$$

We need to find the shortest route visiting each of the four points $\{x_1, x_2, x_3, x_4\}$ exactly once and returning to the start, using the Ant Colony Optimization steps:

1. Initialize pheromone values on all edges to the *artificial pheromone* (0.0453).
2. Place 4 ants on different starting nodes.
3. Compute paths based on probability (influenced by pheromone τ_{ij} and distance via $\eta_{ij} = 1/d_{ij}$).
4. Update pheromone intensities on edges used by ants.
5. Repeat until the maximum iteration (10) or convergence.

Table 1: Distance Matrix d_{ij}

$i \setminus j$	1	2	3	4
1	–	19.03	115.22	77.47
2	19.03	–	100.42	63.17
3	115.22	100.42	–	37.65
4	77.47	63.17	37.65	–

(Values are rounded to 2 decimal places.)

Course	Swarm Intelligence (RB414)		Feb. 2025
Teaching Staff	Dr. Omar Shalash	Eng. Ahmed Métwalli	

Sheet 2: Particle Swarm Optimization

Problem: Communication in Particle Swarm Optimization (PSO)
In Particle Swarm Optimization, each particle communicates implicitly with other particles by sharing information through the global best-known solution (g^{best}). The communication mechanism is defined by the following steps: **Problem: Minimization of the Rastrigin Function (Non-Convex)**
The Rastrigin function is non-convex, multimodal, and a standard benchmark for testing optimization algorithms:

$$f(x) = 20 + x_1^2 - 10\cos(2\pi x_1) + x_2^2 - 10\cos(2\pi x_2)$$

PSO Parameters:

$$\begin{aligned}
&\text{Population Size} = 2,\\
&\text{Maximum Iterations} = 10,\\
&\text{Inertia Weight } (w) = 0.5,\\
&\text{Cognitive Coefficient } (c_1) = 1.5,\\
&\text{Social Coefficient } (c_2) = 2.0.
\end{aligned}$$

Initial Particle Positions and Velocities:

$$\begin{aligned}
x_1^0 &= [4, 5], & v_1^0 &= [0, 0],\\
x_2^0 &= [3, -4], & v_2^0 &= [1, -1].
\end{aligned}$$

Procedure:

1. Evaluate initial fitness for each particle using the Rastrigin function.
2. Determine personal best (p_i^{best}) and global best (g^{best}).
3. Update velocities:
$$v_i^{t+1} = wv_i^t + c_1r_1(p_i^{best} - x_i^t) + c_2r_2(g^{best} - x_i^t)$$
4. Update positions:
$$x_i^{t+1} = x_i^t + v_i^{t+1}$$
5. Repeat until convergence or maximum iterations.

The global minimum is at $(0, 0)$ with $f(0, 0) = 0$, but multiple local minima complicate the optimization. This indirect communication through g^{best} enables particles to explore collectively and find optimal solutions efficiently.