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LAMPIRAN

Lampiran 1. Program Python untuk *Generate* Matriks Jarak

```
import numpy as np
import pandas as pd
from IPython.display import display

# Membuat matriks simetris
def create_symmetric_matrix(n):
    matrix = np.random.randint(1, 30, size=(n, n))  # Matriks
acak dengan angka bulat antara 1 dan 10, dengan ukuran n x n
    symmetric_matrix = (matrix + matrix.T) // 2  # Menggunakan
pembagian bulat untuk memastikan hasilnya tetap integer
    np.fill_diagonal(symmetric_matrix, 0)  # Mengisi diagonal
dengan nol
    return symmetric_matrix

# Membuat matriks tidak simetris
def create_nonsymmetric_matrix(n):
    matrix = np.random.randint(1, 30, size=(n, n))  # Matriks
acak dengan angka bulat antara 1 dan 10, dengan ukuran n x n
    np.fill_diagonal(matrix, 0)  # Mengisi diagonal dengan nol
    return matrix

# Contoh penggunaan
n = 10  # Ukuran matriks
symmetric_matrix = create_symmetric_matrix(n)
nonsymmetric_matrix = create_nonsymmetric_matrix(n)

# Membuat label untuk baris dan kolom
labels = [chr(65+i) for i in range(n)]

# Mengonversi matriks menjadi DataFrame dengan label
symmetric_df = pd.DataFrame(symmetric_matrix, index=labels,
columns=labels)
nonsymmetric_df = pd.DataFrame(nonsymmetric_matrix,
index=labels, columns=labels)

# Menampilkan DataFrame dengan fungsi display()
print("\nMatriks Simetris:")
display(symmetric_df)

print("\nMatriks Asimetris:")
display(nonsymmetric_df)
```

Lampiran 2. Program Python untuk Algoritma *Greedy*

```
import numpy as np

# Fungsi untuk menghitung total jarak dari tur
def total_distance_tour(tour, distance_matrix):
    total_distance = 0
    num_cities = len(tour)
    for i in range(num_cities - 1):
        total_distance += distance_matrix[tour[i], tour[i +
1]]
    # Menambahkan jarak dari kota terakhir kembali ke kota
awal
    total_distance += distance_matrix[tour[num_cities - 1],
tour[0]]
    return total_distance

# Algoritma Greedy untuk menemukan tur terpendek pada TSP
def greedy_tsp(distance_matrix):
    num_cities = distance_matrix.shape[0]
    all_tours = []  # Menyimpan semua tur yang dihasilkan
    for start_city in range(num_cities):
        unvisited_cities = list(range(num_cities))
        current_city = start_city
        tour = [current_city]  # Inisialisasi tur dengan kota
awal
        while unvisited_cities:
            nearest_city = min(unvisited_cities, key=lambda
city: distance_matrix[current_city, city])
            # Memilih kota terdekat sebagai kota berikutnya
            tour.append(nearest_city)
            unvisited_cities.remove(nearest_city)
            # Update (memperbarui) kota saat ini
            current_city = nearest_city
        # Menghitung total jarak tur
        tour_distance = total_distance_tour(tour,
distance_matrix)
        # Menambahkan tur dan total jaraknya ke daftar tur
        all_tours.append((tour, tour_distance))
    return all_tours

# --- PROGRAM UTAMA --- #
if __name__ == "__main__":
    distances = [
        [0, 12, 15, 21, 8],
        [12, 0, 23, 17, 15],
        [15, 23, 0, 9, 13],
```

```
        [21, 17, 9, 0, 7],
        [8, 15, 13, 7, 0]
    ]

    # Membuat matriks jarak menggunakan array NumPy
    distance_matrix = np.array(distances)

    # Mendapatkan semua rute yang mungkin dengan total
jaraknya menggunakan algoritma Greedy untuk TSP
    all_tours = greedy_tsp(distance_matrix)

    # Menampilkan semua rute dan total jaraknya
    print("\nSemua Rute dan Total Jarak TSP:")
    for tour, distance in all_tours:
        print("Rute:", tour, "dengan Total Jarak:", distance)

    # Memilih rute terpendek
    best_tour, best_distance = min(all_tours, key=lambda x:
x[1])

    # Menampilkan rute terpendek dan jaraknya
    print("\nRute Terpendek TSP:", best_tour, "dengan Total
Jarak:", best_distance)
```

Lampiran 3. Program Python untuk Algoritma ACO

```
import numpy as np
import itertools

# Fungsi untuk menghasilkan semua kemungkinan rute
def generate_all_routes(num_cities):
    all_routes = []
    for route in itertools.permutations(range(num_cities)):
        all_routes.append(list(route))  # Mengonversi tuple
rute menjadi list dan menambahkannya ke daftar rute
    return all_routes

# Fungsi untuk menghitung total jarak rute
def total_distance(route, distance_matrix):
    total_distance = 0
    num_cities = len(route)
    for i in range(num_cities - 1):
        total_distance += distance_matrix[route[i], route[i +
1]]  # Menambahkan jarak antar dua kota berturut-turut
    total_distance += distance_matrix[route[-1], route[0]]  #
Menambahkan jarak kembali ke kota awal
    return total_distance

# Algoritma Ant Colony Optimization untuk menemukan rute
terpendek
def ant_colony_optimization(distance_matrix, num_ants, alpha,
beta, iterations):
    num_cities = distance_matrix.shape[0]
    pheromone = np.ones((num_cities, num_cities))  #
Inisialisasi pheromone
    best_distance = float('inf')  # Inisialisasi jarak
terpendek dengan nilai tak hingga
    best_route = None  # Inisialisasi rute terpendek
    all_routes = []  # Inisialisasi daftar untuk menyimpan
semua rute yang dieksplorasi

    for iterasi in range(iterations):
        ants_route = []  # Inisialisasi daftar rute untuk
setiap semut pada iterasi ini

        # Langkah semut
        for ant in range(num_ants):
            visited = [False] * num_cities  # Inisialisasi
daftar kunjungan kota
            current_city = np.random.randint(num_cities)  #
Memilih kota awal secara acak
```

```
            visited[current_city] = True  # Menandai kota awal
sebagai dikunjungi
            route = [current_city]  # Menambahkan kota awal ke
rute

            for _ in range(num_cities - 1):
                p = np.zeros(num_cities)  # Inisialisasi
daftar probabilitas untuk memilih kota berikutnya

                # Hitung probabilitas untuk memilih kota
berikutnya
                for next_city in range(num_cities):
                    if not visited[next_city]:
                        p[next_city] =
(pheromone[current_city, next_city] ** alpha) * \
                                       ((1.0 /
distance_matrix[current_city, next_city]) ** beta)

                # Pilih kota berikutnya berdasarkan
probabilitas
                next_city =
np.random.choice(range(num_cities), p=p / p.sum())
                route.append(next_city)  # Menambahkan kota
berikutnya ke rute
                visited[next_city] = True  # Menandai kota
berikutnya sebagai dikunjungi
                current_city = next_city  # Memperbarui kota
saat ini

            ants_route.append(route)  # Menambahkan rute semut
ke daftar rute semua semut

        # Menampilkan rute untuk iterasi tertentu
        print("Iterasi", iterasi+1)
        for idx, route in enumerate(ants_route):
            distance = total_distance(route, distance_matrix)
            print("Rute", idx+1, ":", route, "dengan Total
Jarak =", distance)

        # Update pheromone
        for i in range(num_ants):
            distance = total_distance(ants_route[i],
distance_matrix)  # Menghitung total jarak rute semut
            if distance < best_distance:
                best_distance = distance  # Memperbarui jarak
terpendek jika ditemukan yang lebih pendek
```

```
                best_route = ants_route[i]  # Memperbarui rute
terpendek jika ditemukan yang lebih pendek

            for j in range(num_cities - 1):
                pheromone[ants_route[i][j], ants_route[i][j +
1]] += 1.0 / distance  # Memperbarui pheromone

        # Penguapan pheromone
        pheromone *= 0.1

        # Memperbarui semua rute yang mungkin
        all_routes.extend(ants_route)  # Menambahkan rute
semut pada iterasi ini ke daftar semua rute

    return all_routes, best_route, best_distance

# --- PROGRAM UTAMA --- #

# Ukuran matriks
num_cities = 5

# Jarak antar kota (inisialisasi manual)
distance_matrix = np.array([
    [0, 12, 15, 21, 8],
    [12, 0, 23, 17, 15],
    [15, 23, 0, 9, 13],
    [21, 17, 9, 0, 7],
    [8, 15, 13, 7, 0]
])

# Parameter algoritma ACO
alpha = 1
beta = 1
num_ants = 5
iterations = 25

# Menjalankan algoritma ACO
all_routes, best_route, best_distance =
ant_colony_optimization(distance_matrix, num_ants, alpha,
beta, iterations)

# Menampilkan rute terpendek dan total jaraknya
print("\nRute Terpendek:", best_route, "dengan Total Jarak =",
best_distance)
```

Lampiran 4. Matriks Jarak yang Digunakan

5 × 5

Matriks Simetris:

	A	B	C	D	E
A	0	12	15	21	8
B	12	0	23	17	15
C	15	23	0	9	13
D	21	17	9	0	7
E	8	15	13	7	0

Matriks Asimetris:

	A	B	C	D	E
A	0	5	2	9	7
B	22	0	26	1	3
C	13	20	0	1	27
D	7	17	10	0	23
E	6	10	17	12	0

10 × 10

Matriks Simetris:

	A	B	C	D	E	F	G	H	I	J
A	0	20	23	3	14	16	26	16	18	25
B	20	0	10	8	11	18	22	14	12	16
C	23	10	0	12	14	14	5	12	10	21
D	3	8	12	0	19	13	23	25	8	18
E	14	11	14	19	0	8	12	26	16	16
F	16	18	14	13	8	0	25	18	9	13
G	26	22	5	23	12	25	0	12	18	5
H	16	14	12	25	26	18	12	0	16	19
I	18	12	10	8	16	9	18	16	0	18
J	25	16	21	18	16	13	5	19	18	0

Matriks Asimetris:

	A	B	C	D	E	F	G	H	I	J
A	0	17	21	23	11	7	18	6	9	10
B	15	0	11	16	27	3	29	9	23	1
C	17	10	0	11	1	7	29	19	17	25
D	12	23	20	0	22	19	20	8	22	11
E	11	14	4	21	0	7	16	3	24	7
F	21	24	25	22	6	0	11	7	26	14
G	3	8	9	8	9	1	0	23	17	28
H	15	10	8	9	23	21	18	0	10	27
I	24	6	3	22	13	26	15	15	0	24
J	10	6	25	17	13	12	17	17	2	0

15 × 15

Matriks Simetris:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	0	18	15	10	12	12	16	5	13	22	6	21	15	11	23
B	18	0	17	10	21	15	21	23	5	21	18	9	15	18	16
C	15	17	0	11	14	7	15	23	14	11	5	20	15	13	16
D	10	10	11	0	18	9	21	11	11	15	18	5	19	15	6
E	12	21	14	18	0	16	23	10	10	11	21	7	19	16	6
F	12	15	7	9	16	0	18	11	12	12	20	13	13	11	16
G	16	21	15	21	23	18	0	17	15	26	11	16	4	6	15
H	5	23	23	11	10	11	17	0	9	6	14	10	11	21	6
I	13	5	14	11	10	12	15	9	0	9	13	12	23	13	10
J	22	21	11	15	11	12	26	6	9	0	15	11	17	5	3
K	6	18	5	18	21	20	11	14	13	15	0	8	18	25	17
L	21	9	20	5	7	13	16	10	12	11	8	0	16	17	22
M	15	15	15	19	19	13	4	11	23	17	18	16	0	28	3
N	11	18	13	15	16	11	6	21	13	5	25	17	28	0	11
O	23	16	16	6	6	16	15	6	10	3	17	22	3	11	0

Matriks Asimetris:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	0	21	22	8	27	14	22	1	21	19	20	13	6	20	25
B	6	0	19	19	14	15	2	20	29	12	12	1	26	23	7
C	27	15	0	15	14	16	15	9	27	16	29	29	20	2	3
D	10	14	7	0	18	3	23	27	15	16	23	22	13	5	12
E	12	24	3	23	0	25	4	28	18	5	3	9	3	18	17
F	12	20	11	14	3	0	17	24	15	10	7	24	23	23	29
G	6	14	20	1	28	27	0	15	11	1	28	14	1	9	3
H	11	11	27	28	17	19	23	0	10	25	14	7	3	28	13
I	27	10	24	23	11	17	16	10	0	5	15	7	9	21	11
J	15	16	20	9	4	3	21	5	25	0	13	8	15	16	2
K	26	15	24	7	19	23	11	5	26	5	0	2	4	28	29
L	5	25	27	4	13	26	27	2	18	9	28	0	25	11	9
M	19	17	3	13	1	6	4	4	2	1	8	16	0	19	23
N	18	28	10	28	3	25	15	12	5	19	26	15	17	0	19
O	4	15	16	3	17	22	4	11	22	2	20	9	3	14	0

20×20

Matriks Simetris:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	0	40	47	61	55	35	70	47	55	81	68	45	32	70	58	28	89	35	78	85
B	40	0	21	8	43	76	47	49	68	55	37	48	71	4	48	64	26	9	36	17
C	47	21	0	55	69	33	72	41	53	89	21	19	26	39	65	34	40	89	21	77
D	61	8	55	0	64	59	52	38	84	76	45	41	54	76	45	72	48	36	34	49
E	55	43	69	64	0	65	56	34	39	10	92	36	42	44	59	56	41	72	34	42
F	35	76	33	59	65	0	76	40	60	27	51	44	85	57	49	70	72	45	45	65
G	70	47	72	52	56	76	0	18	11	94	23	41	70	43	33	44	20	56	56	20
H	47	49	41	38	34	40	18	0	30	18	80	60	44	12	33	56	74	80	35	63
I	55	68	53	84	39	60	11	30	0	28	50	37	18	54	27	42	46	45	69	62
J	81	55	89	76	10	27	94	18	28	0	5	88	71	27	52	57	52	20	9	61
K	68	37	21	45	92	51	23	80	50	5	0	57	22	47	21	72	36	25	37	87
L	45	48	19	41	36	44	41	60	37	88	57	0	58	55	76	17	85	62	78	67
M	32	71	26	54	42	85	70	44	18	71	22	58	0	26	44	72	46	27	12	48
N	70	4	39	76	44	57	43	12	54	27	47	55	26	0	23	66	59	62	76	45
O	58	48	65	45	59	49	33	33	27	52	21	76	44	23	0	50	69	89	94	76
P	28	64	34	72	56	70	44	56	42	57	72	17	72	66	50	0	29	48	24	48
Q	89	26	40	48	41	72	20	74	46	52	36	85	46	59	69	29	0	35	54	49
R	35	9	89	36	72	45	56	80	45	20	25	62	27	62	89	48	35	0	40	47
S	78	36	21	34	34	45	56	35	69	9	37	78	12	76	94	24	54	40	0	45
T	85	17	77	49	42	65	20	63	62	61	87	67	48	45	76	48	49	47	45	0

Matriks Asimetris:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	0	26	22	21	54	69	57	76	64	30	79	64	63	30	53	65	26	20	68	5
B	93	0	32	11	2	10	42	71	41	47	27	76	44	57	59	27	19	27	59	31
C	81	58	0	84	32	54	4	38	60	70	26	41	5	42	9	87	21	84	20	51
D	46	20	1	0	40	84	9	39	90	32	21	56	22	13	98	10	40	61	53	92
E	10	49	48	75	0	71	75	88	6	26	20	43	24	17	31	63	39	35	59	55
F	44	79	39	80	17	0	99	56	94	45	53	14	10	6	98	90	63	51	70	27
G	4	96	44	71	2	6	0	30	52	44	48	18	55	13	43	2	37	63	29	41
H	94	83	60	52	35	74	14	0	23	43	39	93	14	38	32	99	76	80	22	72
I	1	35	15	24	21	85	26	77	0	1	34	7	33	48	72	16	12	6	24	75
J	23	47	53	7	73	25	41	33	83	0	62	25	9	47	55	88	11	35	31	22
K	38	39	24	33	20	62	94	95	10	80	0	8	79	87	70	10	42	29	61	78
L	91	60	17	58	94	19	40	12	4	44	98	0	76	87	89	56	53	89	39	1
M	2	76	68	63	99	37	61	14	11	7	70	46	0	24	33	67	27	24	36	3
N	85	73	17	68	94	78	27	86	35	33	84	13	27	0	15	86	56	61	29	26
O	77	3	83	47	93	32	81	49	80	19	60	77	52	40	0	73	37	46	80	44
P	35	35	26	65	81	54	2	10	69	88	47	46	22	37	84	0	50	15	20	71
Q	42	43	69	40	31	15	4	86	45	18	2	64	40	10	47	80	0	21	15	59
R	99	6	95	4	93	83	56	1	73	71	54	39	73	4	19	92	18	0	71	90
S	18	49	71	63	13	93	89	73	98	81	60	5	64	66	86	43	17	42	0	65
T	45	87	22	95	21	71	84	50	4	8	96	54	38	33	66	19	79	14	80	0

50×50

Matriks Simetris (secara keseluruhan):

0, 80, 43, 52, 19, 69, 80, 49, 41, 42, 85, 82, 37, 86, 67, 51, 44, 54, 65, 57, 68, 75, 75, 77, 62, 74, 83, 89, 21, 54, 76, 78, 56, 35, 76, 75, 78, 43, 44, 34, 38, 75, 45, 77, 17, 18, 65, 89, 23, 41
80, 0, 78, 23, 31, 62, 82, 27, 28, 75, 21, 72, 68, 72, 43, 54, 41, 31, 47, 55, 34, 25, 36, 68, 47, 58, 25, 24, 79, 53, 19, 50, 59, 10, 92, 74, 36, 48, 33, 56, 67, 41, 72, 68, 43, 42, 35, 80, 61, 31
43, 78, 0, 81, 48, 43, 56, 69, 66, 29, 44, 48, 55, 78, 59, 33, 45, 43, 27, 43, 56, 59, 64, 43, 4, 62, 68, 47, 81, 93, 19, 24, 73, 36, 69, 49, 66, 73, 56, 47, 49, 28, 62, 92, 65, 50, 38, 28, 55, 57
52, 23, 81, 0, 34, 30, 37, 74, 85, 82, 30, 69, 38, 58, 38, 63, 33, 45, 58, 32, 80, 63, 36, 64, 30, 47, 43, 70, 69, 70, 27, 40, 39, 31, 87, 73, 32, 63, 11, 22, 35, 4, 54, 45, 56, 9, 32, 57, 14, 58
19, 31, 48, 34, 0, 51, 75, 74, 44, 7, 89, 91, 50, 53, 17, 25, 33, 73, 36, 48, 57, 61, 57, 4, 43, 25, 40, 56, 37, 20, 70, 49, 67, 33, 58, 70, 59, 74, 38, 64, 47, 29, 56, 36, 56, 60, 65, 57, 84, 62
69, 62, 43, 30, 51, 0, 43, 61, 61, 77, 11, 50, 61, 61, 37, 28, 43, 45, 81, 51, 59, 68, 39, 53, 54, 68, 68, 55, 5, 30, 17, 40, 40, 51, 17, 39, 61, 46, 82, 74, 64, 21, 91, 59, 23, 53, 73, 69, 68, 62
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41, 28, 66, 85, 44, 61, 28, 56, 0, 52, 81, 71, 44, 39, 46, 36, 50, 64, 73, 24, 93, 87, 42, 65, 42, 54, 49, 90, 61, 93, 61, 51, 38, 85, 72, 22, 82, 45, 42, 26, 56, 51, 62, 28, 67, 65, 61, 46, 34, 23
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37, 68, 55, 38, 50, 61, 66, 68, 44, 56, 59, 4, 0, 77, 64, 44, 29, 90, 26, 84, 26, 51, 37, 61, 73, 59, 72, 42, 59, 15, 58, 52, 42, 48, 23, 70, 62, 49, 37, 39, 36, 65, 31, 19, 41, 32, 29, 19, 39, 26
86, 72, 78, 58, 53, 61, 46, 57, 39, 51, 52, 64, 77, 0, 51, 24, 6, 66, 46, 51, 75, 63, 33, 27, 41, 57, 68, 54, 69, 79, 69, 24, 91, 43, 45, 57, 39, 44, 64, 53, 50, 42, 72, 48, 35, 55, 69, 40, 47, 69
67, 43, 59, 38, 17, 37, 60, 31, 46, 64, 25, 38, 64, 51, 0, 61, 47, 48, 25, 64, 37, 43, 53, 73, 50, 81, 73, 39, 33, 91, 68, 54, 78, 38, 31, 60, 56, 35, 49, 74, 61, 51, 38, 6, 60, 31, 76, 95, 81, 72
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21, 79, 81, 69, 37, 5, 21, 82, 61, 25, 74, 40, 59, 69, 33, 30, 23, 61, 69, 41, 59, 47, 26, 49, 38, 54, 37, 69, 0, 44, 49, 10, 28, 27, 51, 37, 63, 41, 65, 45, 52, 18, 44, 58, 49, 48, 58, 87, 72, 59
54, 53, 93, 70, 20, 30, 10, 13, 93, 54, 49, 19, 15, 79, 91, 19, 46, 30, 19, 49, 73, 56, 66, 88, 18, 28, 21, 47, 44, 0, 43, 56, 89, 46, 76, 51, 80, 17, 31, 72, 43, 51, 66, 71, 34, 50, 72, 55, 46, 45
76, 19, 19, 27, 70, 17, 79, 58, 61, 53, 63, 5, 58, 69, 68, 44, 46, 50, 55, 58, 27, 25, 51, 76, 65, 50, 76, 29, 49, 43, 0, 44, 35, 39, 78, 37, 50, 75, 30, 30, 54, 87, 56, 51, 33, 87, 36, 45, 25, 52
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44, 33, 56, 11, 38, 82, 45, 43, 42, 49, 54, 58, 37, 64, 49, 25, 78, 53, 9, 42, 33, 51, 80, 43, 29, 53, 41, 44, 65, 31, 30, 81, 50, 26, 26, 62, 41, 64, 0, 84, 41, 59, 27, 38, 38, 63, 65, 7, 26, 20
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Matriks Asimetris (secara keseluruhan):

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76, 93, 96, 56, 0, 70, 42, 74, 91, 18, 65, 38, 69, 96, 70, 49, 49, 33, 18, 51, 48, 84, 8, 54, 75, 12, 1, 53, 85, 61, 47, 72, 39, 27, 63, 2, 22, 76, 29, 3, 54, 82, 3, 36, 79, 8, 63, 67, 94, 81
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47, 35, 38, 49, 11, 91, 0, 96, 23, 60, 4, 62, 53, 40, 66, 91, 73, 64, 62, 60, 11, 49, 43, 30, 22, 7, 79, 77, 70, 61, 32, 52, 71, 40, 85, 63, 57, 37, 4, 15, 35, 8, 50, 59, 87, 58, 35, 28, 73, 63
5, 97, 64, 30, 86, 26, 21, 0, 98, 86, 30, 96, 38, 15, 25, 96, 33, 35, 53, 5, 38, 21, 90, 91, 72, 77, 85, 36, 35, 55, 3, 23, 11, 55, 7, 55, 58, 7, 19, 99, 24, 51, 7, 42, 40, 23, 97, 84, 98, 57
29, 32, 21, 96, 18, 68, 34, 93, 0, 77, 93, 35, 78, 43, 76, 84, 12, 18, 51, 23, 29, 58, 22, 24, 86, 60, 96, 61, 91, 43, 97, 63, 75, 8, 26, 18, 60, 40, 24, 63, 30, 76, 71, 78, 1, 70, 74, 79, 61, 82
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38, 7, 75, 10, 87, 50, 5, 74, 78, 50, 0, 60, 70, 68, 42, 25, 79, 25, 69, 76, 9, 51, 36, 33, 9, 36, 61, 67, 50, 66, 47, 70, 11, 92, 65, 15, 91, 21, 93, 46, 5, 29, 91, 11, 14, 51, 59, 47, 97, 74
59, 56, 75, 74, 87, 31, 31, 26, 80, 30, 82, 0, 67, 13, 87, 66, 80, 46, 80, 67, 83, 66, 56, 90, 20, 84, 75, 33, 1, 10, 78, 59, 26, 20, 60, 27, 53, 57, 23, 83, 39, 35, 74, 15, 39, 39, 72, 87, 12, 30
13, 89, 84, 59, 79, 62, 42, 7, 68, 26, 87, 67, 0, 6, 39, 6, 56, 57, 88, 21, 87, 66, 93, 34, 63, 62, 66, 9, 61, 2, 97, 5, 26, 40, 95, 56, 8, 76, 33, 26, 10, 14, 88, 46, 38, 54, 86, 43, 42, 22
44, 70, 38, 23, 79, 37, 10, 53, 71, 65, 61, 97, 54, 0, 48, 89, 13, 11, 23, 20, 18, 80, 97, 62, 33, 32, 49, 60, 31, 82, 89, 62, 22, 94, 9, 19, 67, 63, 49, 91, 43, 45, 34, 19, 68, 56, 15, 30, 76, 42
78, 77, 64, 53, 85, 22, 42, 51, 77, 51, 14, 90, 59, 45, 0, 3, 17, 18, 93, 17, 64, 58, 44, 64, 12, 56, 5, 27, 57, 24, 11, 21, 79, 58, 79, 34, 67, 37, 92, 96, 83, 10, 84, 63, 26, 80, 97, 9, 50, 78
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24, 71, 48, 43, 79, 59, 48, 78, 2, 18, 83, 91, 52, 96, 70, 26, 8, 0, 24, 92, 28, 31, 41, 94, 16, 98, 27, 49, 92, 54, 26, 30, 88, 31, 97, 32, 6, 25, 81, 17, 10, 79, 31, 49, 13, 12, 16, 48, 95, 25
17, 41, 2, 60, 78, 42, 84, 43, 51, 39, 22, 15, 3, 31, 73, 79, 7, 34, 0, 77, 58, 91, 4, 83, 99, 98, 31, 57, 46, 33, 72, 12, 4, 43, 63, 81, 66, 8, 50, 12, 54, 95, 72, 71, 20, 62, 14, 69, 30, 40
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84, 13, 45, 91, 99, 34, 25, 31, 65, 64, 52, 31, 68, 91, 9, 8, 46, 4, 7, 25, 0, 2, 63, 27, 66, 49, 68, 39, 35, 87, 64, 7, 66, 86, 19, 13, 9, 60, 65, 61, 42, 38, 23, 79, 79, 13, 43, 37, 78, 26
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73, 24, 82, 52, 79, 47, 72, 26, 49, 86, 46, 28, 57, 70, 61, 84, 71, 22, 74, 15, 3, 68, 47, 0, 99, 23, 76, 95, 61, 89, 9, 12, 13, 94, 92, 26, 58, 40, 99, 57, 68, 77, 87, 35, 87, 80, 4, 38, 38, 28
77, 28, 53, 7, 98, 38, 76, 6, 50, 47, 29, 37, 2, 91, 97, 84, 2, 15, 60, 65, 7, 28, 20, 18, 0, 4, 46, 44, 63, 59, 68, 76, 89, 88, 50, 40, 25, 85, 47, 64, 99, 93, 65, 17, 24, 68, 75, 58, 14, 48
73, 93, 90, 80, 77, 53, 11, 25, 95, 65, 74, 47, 45, 99, 31, 55, 61, 70, 6, 73, 97, 62, 90, 74, 13, 0, 51, 23, 3, 4, 23, 89, 50, 8, 63, 68, 62, 94, 72, 32, 31, 16, 14, 93, 60, 77, 80, 62, 48, 98
65, 21, 83, 80, 6, 15, 4, 69, 55, 16, 65, 99, 34, 29, 51, 22, 89, 73, 13, 67, 84, 79, 31, 10, 45, 95, 0, 54, 40, 91, 16, 59, 41, 52, 44, 38, 97, 1, 30, 13, 5, 41, 29, 50, 49, 32, 77, 48, 19, 62
71, 99, 70, 83, 57, 34, 94, 17, 67, 59, 96, 31, 22, 26, 26, 64, 92, 45, 42, 60, 49, 27, 48, 75, 30, 25, 88, 0, 37, 75, 63, 86, 29, 87, 69, 79, 77, 32, 90, 70, 27, 88, 25, 35, 29, 34, 30, 68, 49, 75
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71, 8, 41, 88, 89, 88, 53, 94, 30, 16, 44, 31, 95, 1, 87, 77, 38, 30, 63, 63, 39, 14, 71, 28, 29, 87, 62, 81, 61, 0, 44, 64, 4, 21, 16, 25, 26, 23, 47, 39, 8, 80, 40, 43, 58, 21, 64, 50, 21, 81
93, 31, 26, 8, 35, 53, 11, 86, 96, 96, 29, 19, 73, 78, 93, 74, 65, 74, 9, 12, 31, 30, 74, 54, 3, 23, 71, 67, 45, 78, 0, 56, 94, 3, 51, 87, 57, 91, 96, 8, 18, 21, 84, 71, 7, 12, 3, 33, 47, 12
24, 55, 83, 71, 82, 28, 48, 56, 52, 28, 20, 39, 82, 12, 33, 78, 57, 40, 52, 86, 35, 44, 87, 17, 9, 3, 90, 39, 80, 18, 54, 0, 84, 91, 35, 87, 45, 25, 11, 33, 69, 67, 83, 20, 5, 54, 11, 78, 90, 87
33, 15, 83, 22, 70, 77, 40, 43, 33, 77, 55, 86, 51, 52, 16, 29, 8, 37, 58, 78, 55, 29, 80, 89, 74, 86, 65, 5, 65, 36, 72, 30, 0, 39, 79, 86, 55, 4, 4, 9, 22, 80, 92, 52, 27, 4, 58, 28, 37, 53
15, 72, 85, 85, 27, 40, 92, 66, 5, 42, 56, 97, 79, 9, 73, 46, 98, 92, 7, 10, 30, 24, 10, 84, 88, 65, 23, 83, 5, 22, 88, 94, 79, 0, 14, 10, 46, 52, 13, 30, 61, 44, 66, 86, 12, 93, 81, 92, 4, 95
9, 1, 69, 59, 39, 81, 55, 28, 2, 70, 65, 67, 97, 56, 87, 69, 53, 32, 69, 73, 16, 41, 24, 56, 51, 33, 4, 17, 81, 61, 98, 44, 69, 54, 0, 21, 13, 70, 22, 15, 10, 85, 87, 62, 7, 40, 52, 64, 70, 63
11, 75, 38, 49, 97, 18, 80, 79, 70, 71, 25, 57, 11, 9, 96, 18, 15, 97, 99, 22, 18, 54, 44, 20, 6, 72, 54, 33, 39, 18, 36, 95, 93, 11, 46, 0, 68, 22, 50, 54, 43, 98, 67, 42, 40, 3, 61, 62, 68, 66
84, 65, 46, 81, 51, 59, 56, 33, 33, 70, 61, 92, 21, 97, 79, 72, 73, 37, 29, 18, 98, 44, 18, 86, 80, 46, 76, 55, 90, 7, 59, 90, 2, 75, 76, 47, 0, 21, 51, 90, 20, 59, 19, 73, 33, 43, 54, 53, 7, 93
57, 36, 58, 70, 68, 11, 12, 5, 69, 27, 89, 28, 86, 25, 49, 23, 73, 53, 42, 46, 57, 42, 89, 32, 26, 22, 39, 70, 28, 55, 77, 2, 96, 53, 81, 48, 85, 0, 50, 48, 88, 65, 84, 14, 89, 99, 91, 28, 37, 30
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83, 53, 34, 91, 1, 51, 2, 46, 45, 70, 13, 89, 99, 10, 39, 13, 26, 36, 27, 81, 56, 77, 45, 77, 9, 59, 73, 37, 42, 55, 36, 42, 87, 16, 67, 89, 25, 21, 26, 68, 5, 0, 77, 22, 10, 38, 25, 81, 90, 19
36, 99, 3, 34, 2, 92, 52, 32, 61, 69, 18, 93, 84, 65, 20, 26, 72, 90, 3, 74, 39, 71, 46, 62, 58, 77, 43, 15, 29, 26, 45, 52, 81, 93, 14, 72, 11, 66, 44, 83, 60, 54, 0, 24, 52, 38, 10, 9, 94, 88
58, 26, 82, 37, 11, 17, 83, 76, 15, 36, 80, 92, 19, 57, 81, 99, 44, 39, 90, 83, 40, 91, 62, 62, 98, 62, 65, 11, 88, 57, 38, 15, 20, 2, 43, 54, 95, 22, 0, 88, 24, 56, 67, 16, 1
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69, 94, 87, 80, 24, 97, 27, 92, 38, 63, 38, 2, 46, 91, 5, 87, 31, 68, 71, 55, 47, 22, 90, 20, 25, 20, 64, 56, 44, 24, 61, 36, 28, 43, 60, 47, 49, 71, 24, 83, 46, 28, 37, 64, 50, 15, 0, 76, 72, 47
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62, 27, 52, 69, 44, 69, 86, 27, 53, 64, 94, 41, 79, 84, 68, 37, 52, 56, 67, 13, 50, 10, 11, 71, 66, 14, 50, 34, 21, 52, 56, 23, 79, 86, 38, 28, 28, 40, 87, 82, 69, 85, 3, 90, 65, 43, 16, 33, 74, 0
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