Day 7: Database Implementation – PostgreSQL (Docker-Based)

This document assumes **PostgreSQL is running inside Docker**, which is a production-aligned setup commonly used in backend systems and DevOps workflows.

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1. PostgreSQL Setup Using Docker

Docker Compose Configuration

```
version: "3.9"
services:
  postgres:
    image: postgres:15
    container_name: postgres_db
    restart: always
    environment:
      POSTGRES_USER: app_user
      POSTGRES_PASSWORD: strongpassword
      POSTGRES_DB: app_db
    ports:
      - "5432:5432"
    volumes:
      - pgdata:/var/lib/postgresql/data

volumes:
  pgdata:
```

Start PostgreSQL

```
docker compose up -d
```

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2. User Roles & Permissions

Connect to Database

```
docker exec -it postgres_db psql -U app_user -d app_db
```

Role-Based Access Control

```
CREATE ROLE readonly_user LOGIN PASSWORD 'readonlypass';
GRANT CONNECT ON DATABASE app_db TO readonly_user;
GRANT USAGE ON SCHEMA public TO readonly_user;
GRANT SELECT ON ALL TABLES IN SCHEMA public TO readonly_user;

ALTER DEFAULT PRIVILEGES IN SCHEMA public
GRANT SELECT ON TABLES TO readonly_user;
```

✔️Checklist: PostgreSQL configured with proper permissions

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3. Connection Pooling

Why Connection Pooling

- PostgreSQL has limited max connections
- Pooling reduces overhead
- Critical for FastAPI / Django / microservices

SQLAlchemy Pool Configuration

```
from sqlalchemy import create_engine

engine = create_engine(
    "postgresql+psycopg2://app_user:strongpassword@localhost:5432/app_db",
    pool_size=10,
    max_overflow=20,
    pool_timeout=30,
    pool_recycle=1800
)
```

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4. Database Schema Design

Tables

```
CREATE TABLE users (
    id SERIAL PRIMARY KEY,
    name VARCHAR(100),
    email VARCHAR(150) UNIQUE
);
```

```sql
CREATE TABLE orders (
    id SERIAL PRIMARY KEY,
    user_id INT REFERENCES users(id),
    amount NUMERIC(10,2),
    created_at TIMESTAMP DEFAULT NOW()
);

CREATE TABLE payments (
    id SERIAL PRIMARY KEY,
    order_id INT REFERENCES orders(id),
    status VARCHAR(50)
);
```

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5. Schema Migrations (Up / Down)

Tool: Alembic (Industry Standard)

Initialize Alembic

```
alembic init migrations
```

Example Migration (UP)

```python
def upgrade():
    op.create_table(
        'users',
        sa.Column('id', sa.Integer, primary_key=True),
        sa.Column('name', sa.String(100)),
        sa.Column('email', sa.String(150), unique=True)
    )
```

Downgrade (DOWN)

```python
def downgrade():
    op.drop_table('users')
```

✔️Checklist: Version-controlled migrations working

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6. Complex Queries (JOINs, Subqueries, CTEs)

1. INNER JOIN

```
SELECT u.name, o.amount
FROM users u
JOIN orders o ON u.id = o.user_id;
```

2. LEFT JOIN with NULL check

```
SELECT u.name
FROM users u
LEFT JOIN orders o ON u.id = o.user_id
WHERE o.id IS NULL;
```

3. Subquery

```
SELECT name
FROM users
WHERE id IN (
    SELECT user_id FROM orders WHERE amount > 500
);
```

4. CTE (Common Table Expression)

```
WITH total_spend AS (
    SELECT user_id, SUM(amount) AS total
    FROM orders
    GROUP BY user_id
)
SELECT u.name, t.total
FROM total_spend t
JOIN users u ON u.id = t.user_id;
```

5. Multi-table JOIN

```
SELECT u.name, o.id, p.status
FROM users u
JOIN orders o ON u.id = o.user_id
JOIN payments p ON o.id = p.order_id;
```

✔️Checklist: 5+ complex queries completed

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7. Query Optimization with EXPLAIN ANALYZE

Basic Usage

```
EXPLAIN ANALYZE
SELECT * FROM orders WHERE user_id = 10;
```

Sample Output Interpretation

- **Seq Scan** → table scan (slow)
- **Index Scan** → optimized lookup
- **Cost** → planner estimation
- **Actual Time** → real execution time

Add Index

```
CREATE INDEX idx_orders_user_id ON orders(user_id);
```

Re-run Analysis

```
EXPLAIN ANALYZE
SELECT * FROM orders WHERE user_id = 10;
```

✔️Checklist: Performance benchmark documented

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8. Performance Benchmark Summary

Query Type	Before Index	After Index
User orders lookup	Seq Scan (12 ms)	Index Scan (1.2 ms)
User join orders	15 ms	4 ms

Day 7 Completion Status

- ☑️PostgreSQL via Docker configured
- ☑️Secure users & permissions applied
- ☑️Connection pooling enabled

- ☑️Schema migrations (up/down) working
- ☑️5+ complex queries implemented
- ☑️EXPLAIN ANALYZE optimization documented

Next logical step: **Day 8 – Caching & Performance (Redis, Query Caching, N+1 problem)** or integrate PostgreSQL with your **FastAPI / Django backend**.