**b) What is the core concept of the Two wheeled self-balancing robots (TWSBR).**

### **Core Concept of Two-Wheeled Self-Balancing Robots (TWSBR)**

The core concept of two-wheeled self-balancing robots (TWSBR) revolves around maintaining balance and stability through continuous adjustments based on sensor feedback and control algorithms. This involves several key principles:

1. Inverted Pendulum Model:
   * Concept: TWSBRs operate similarly to an inverted pendulum, where the robot’s body is the pendulum that needs to be balanced upright on its wheels. The goal is to keep the center of gravity directly above the pivot point (wheels).
2. Feedback Control System:
   * Sensors: TWSBRs use sensors like accelerometers and gyroscopes to measure the tilt angle and rate of rotation of the robot.
   * Control Algorithms: A control algorithm, often a PID (Proportional-Integral-Derivative) controller, processes the sensor data and determines the necessary wheel movements to maintain balance. The algorithm continuously adjusts the wheel speeds to correct any deviations from the upright position.
3. Actuators (Motors):
   * Wheel Control: The wheels are driven by motors that can move forward and backward. By adjusting the speed and direction of the wheels, the robot can counteract the tilting motion and stay balanced.
   * Torque Application: The motors apply torque to the wheels to generate the necessary corrective forces to keep the robot upright.
4. Real-time Processing:
   * Fast Response: The control system must operate in real-time, with rapid sensor data acquisition and processing to provide immediate corrective actions.
   * Stability: Ensuring stability requires precise and timely adjustments, as even small delays or inaccuracies can lead to a loss of balance.
5. Sensor Fusion:
   * Combining Data: Combining data from multiple sensors (accelerometers, gyroscopes, sometimes magnetometers) helps improve the accuracy of the robot's state estimation, leading to better balance control.
   * Kalman Filter: Often, a Kalman filter is used for sensor fusion to provide a more accurate estimate of the robot's tilt angle and angular velocity.

### Detailed Explanation:

1. Inverted Pendulum Model:
   * The robot is modeled as an inverted pendulum, where the wheels are the pivot point and the body is the pendulum that needs to be balanced.
2. Feedback Control System:
   * Sensors: Measure the robot’s tilt angle and angular velocity.
   * PID Controller: Adjusts the motor commands to maintain the balance. The PID controller continuously calculates the error between the desired upright position and the current tilt angle, and then it applies corrective actions based on proportional, integral, and derivative terms.
3. Actuators (Motors):
   * Motors: Drive the wheels forward or backward to correct the robot’s tilt. By moving the wheels in the direction of the tilt, the robot can bring itself back to an upright position.
   * Wheel Encoders: Provide feedback on the wheel positions and speeds, which helps in precise control.
4. Real-time Processing:
   * The control system must process sensor data and compute the motor commands within milliseconds to ensure timely corrections and maintain stability.
5. Sensor Fusion:
   * Combining Sensor Data: Improves the accuracy of tilt and velocity estimates.
   * Kalman Filter: A commonly used method for sensor fusion, providing an optimal estimate by considering the noise and uncertainties in sensor measurements.

By integrating these concepts, a two-wheeled self-balancing robot can effectively maintain its balance, navigate its environment, and respond to disturbances. The combination of accurate sensor measurements, robust control algorithms, and responsive actuators enables the robot to perform tasks that require dynamic stability.