# Lecture No. 60
# Stepper Motor

Lecture delivered by:

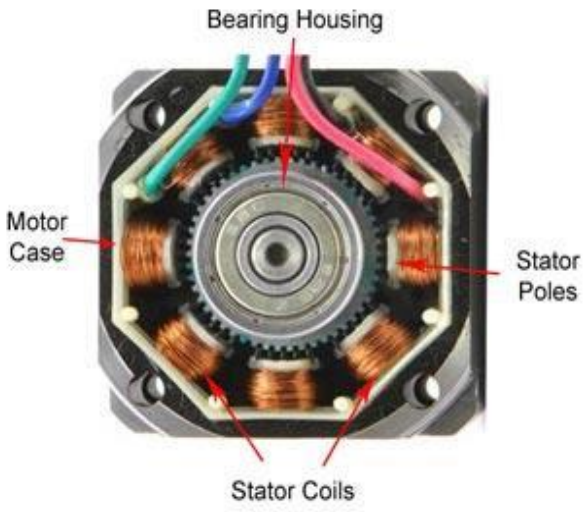
# Objectives

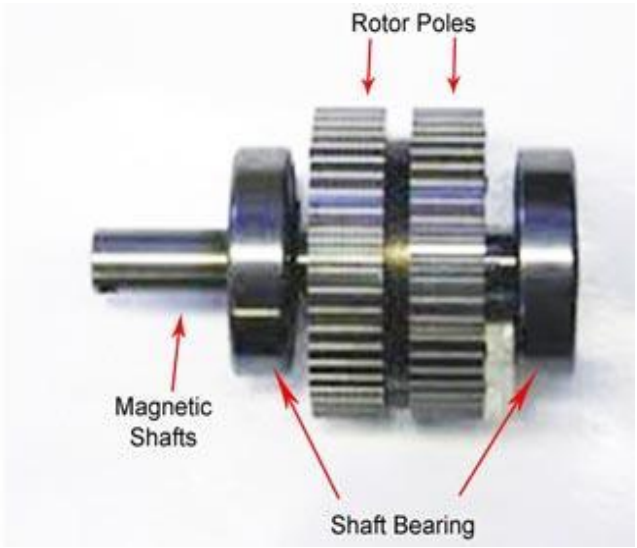
At the end of this lecture, student will be able to:

- Differentiate Stepper Motor from conventional motors
- Classify Stepper Motors based on construction
- Explain the Stepper Motor Principle of Operation

# Definition of Stepper Motor

- **Stepper Motors** therefore are manufactured with steps per revolution of 12, 24, 72, 144, 180, and 200, resulting in stepping angles of 30, 15, 5, 2.5, 2, and 1.8 degrees per step
- Stepper motor can be controlled with or without feedback



# Introduction

- The essential property of the stepping motor is its ability to translate switched excitation changes into precisely defined increments of rotor position (‘steps’)
- Stepping motors are categorized as
  - doubly salient machines

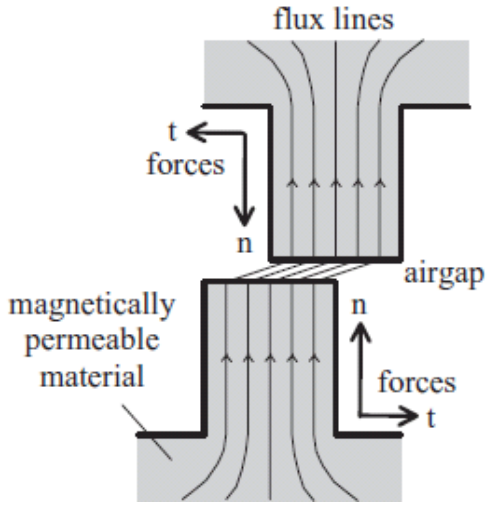



Figure 1: Force components between two magnetically permeable teeth

# Introduction

- According to the type of motor, the source of flux may be a permanent-magnet or a current-carrying winding or a combination of the two
- However, the effect is the same: the teeth experience equal and opposite forces, which attempt to pull them together and minimize the air-gap between them

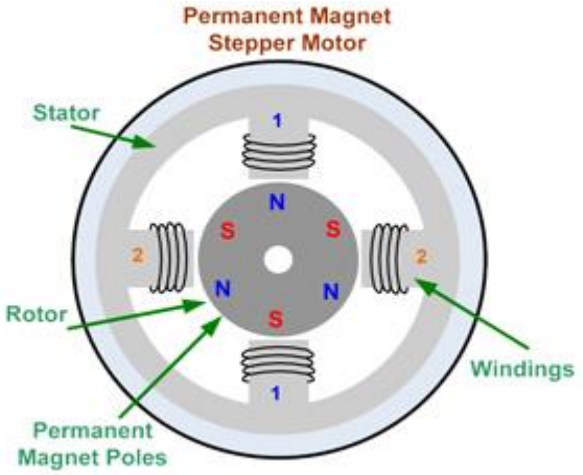
# Types of Stepper motor

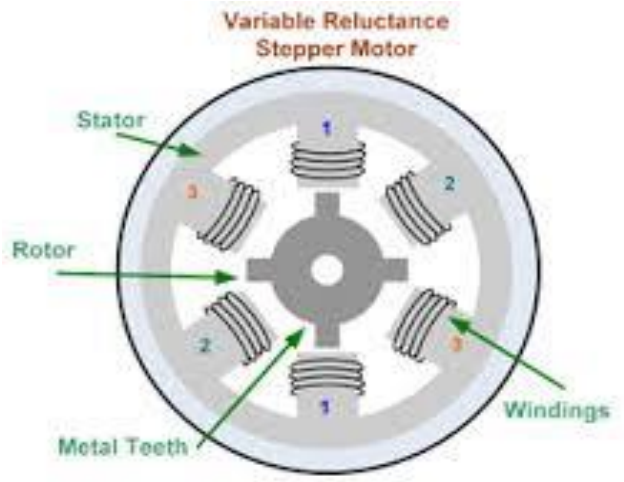
## Permanent Magnet Motor

- Employ Permanent magnet
- Low speed, relatively high torque

## Variable Reluctance Motor

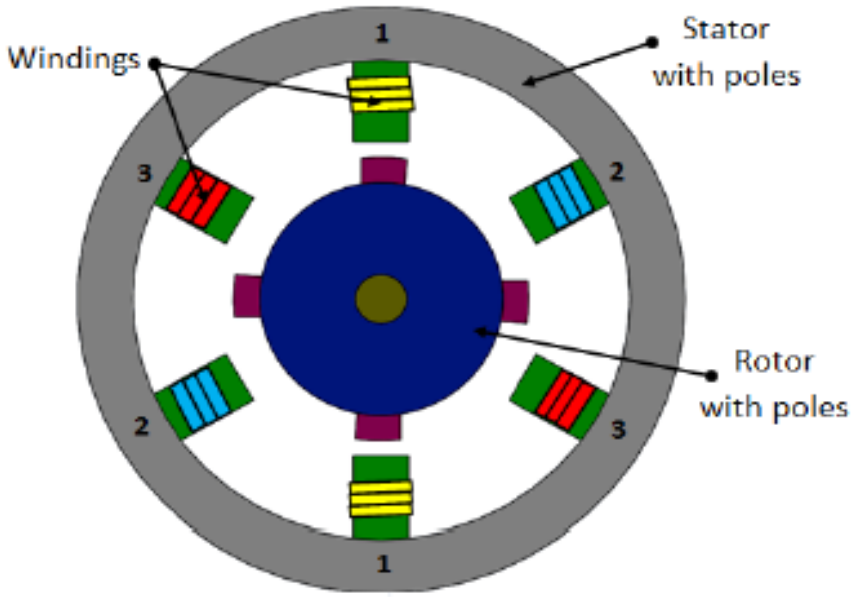
- Does not have Permanent magnet
- Low torque



# Construction of Variable Reluctance Motor

- Cylindrical rotor is made of soft steel and has four poles
- It has four rotor teeth, $90^o$ apart and six stator poles, $60^o$ apart




Source: NPTEL

# Variable Reluctance Motor

- Electromagnetic field is produced by activating the stator coils in sequence. It attracts the metal rotor
- When the windings are energized in a reoccurring sequence of 2, 3, 1, and so on, the motor will rotate in a $30^{o}$ step angle.
- In the non-energized condition, there is no magnetic flux in the air gap, as the stator is an electromagnet and the rotor is a piece of soft iron; hence, there is no detent torque.

# Variable Reluctance Motor

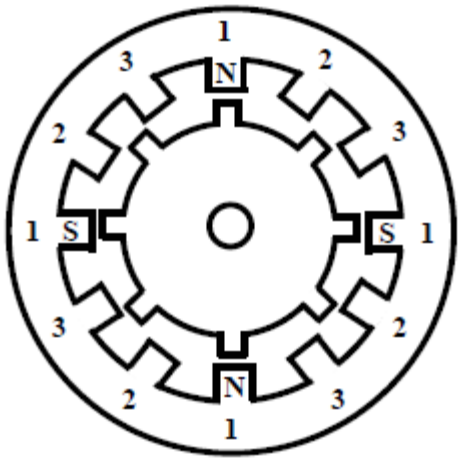
- When a particular stator coil is excited, the rotor aligns itself such that one pair of teeth is along the energized stator coil, at the minimum reluctance path
- Full step angle is derived by stator pole teeth and rotor pole teeth, given by:

Stator pole pitch:

$$\theta_s = \frac{360^0}{\text{Number of stator pole teeth}} = \frac{360^0}{12} = 30^0.$$

Rotor pole pitch:

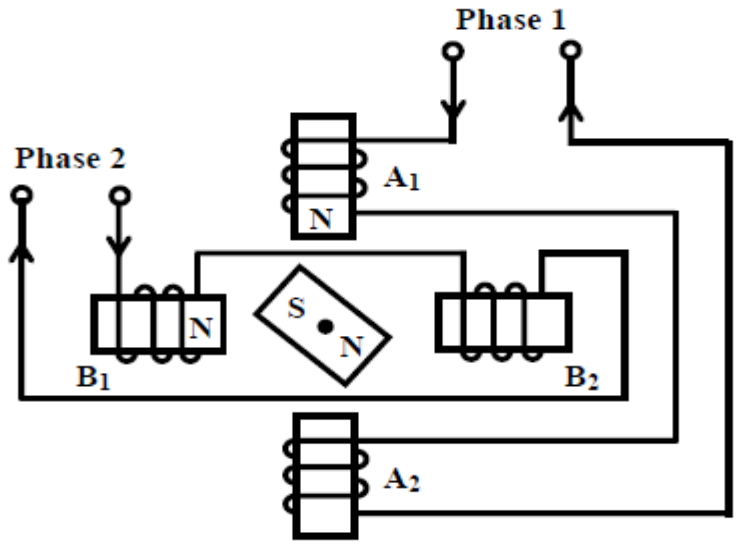
$$\theta_r = \frac{360^0}{\text{Number of rotor pole teeth}} = \frac{360^0}{8} = 45^0$$




$$\text{full step angle } \theta_{fs} = \theta_s \sim \theta_r = 45^0 - 30^0 = 15^0$$

# Permanent Magnet Step Motor

- Two phase two pole permanent magnet step motor

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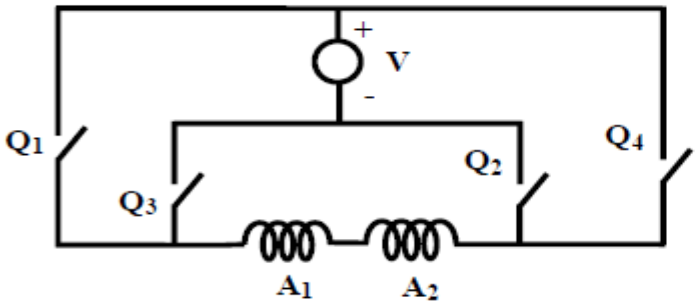
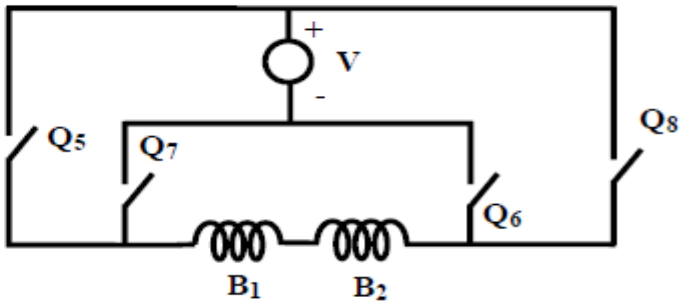
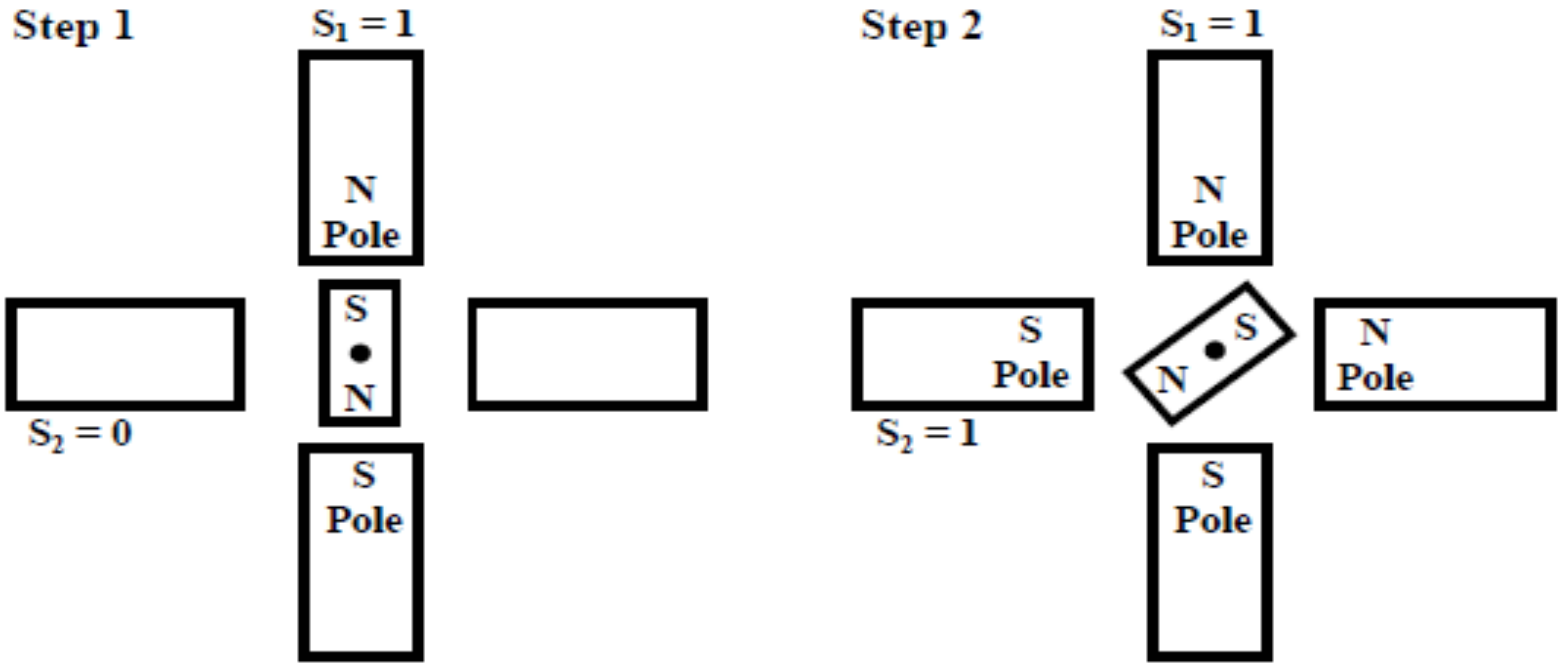
Switching Sequence



# Stepping sequence (half-stepping) for a two-phase two-pole PM step motor for clockwise rotation



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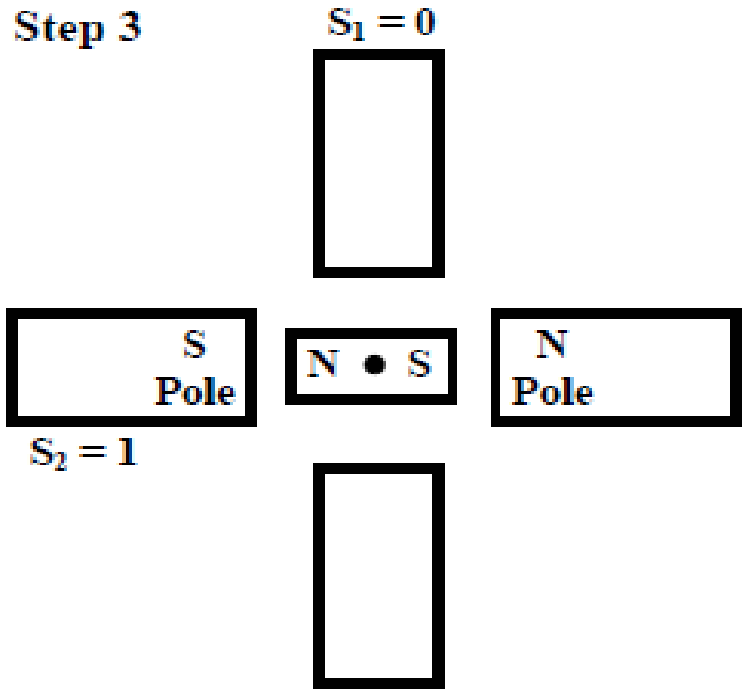


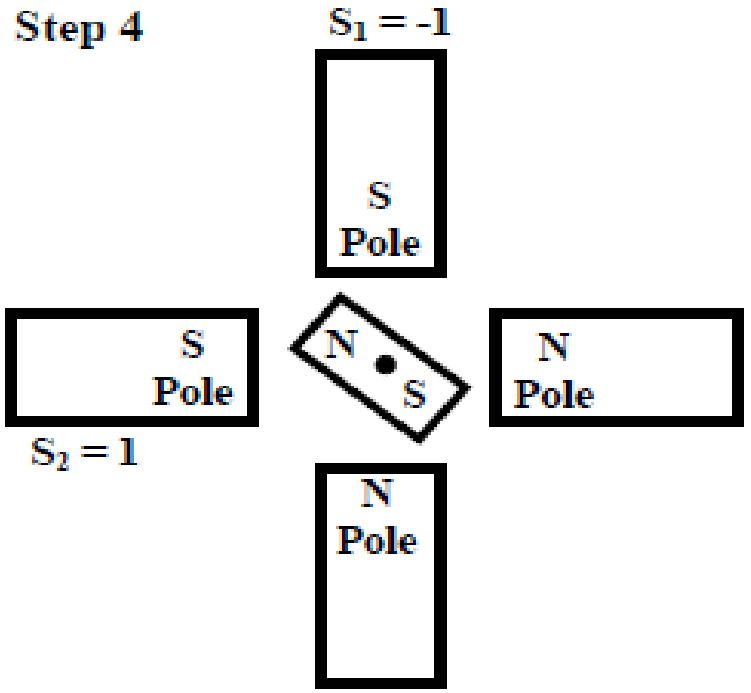

# Switching sequence according to movement

| | Step 1 | Step 2 | Step 3 | Step 4 |
|---|---|---|---|---|
| $Q_1$-$Q_2$ | ON ($S_1$=1) | ON ($S_1$=1) | | |
| $Q_3$-$Q_4$ | | | | ON ($S_1$= -1) |
| $Q_5$-$Q_6$ | | | | |
| $Q_7$-$Q_8$ | | ON ($S_2$=1) | ON ($S_2$=1) | ON ($S_2$=1) |

# Advantage and Disadvantage

- Advantage of a permanent magnet step motor is that it has a holding torque ➡ that due to the presence of permanent magnet the rotor will lock itself along the stator pole even when the excitation coils are de-energized.
- Major disadvantage is that the direction of current for each winding needs to be reversed. This requires more number of transistor switches that may make the driving circuit unwieldy

# Advantages of stepper motors

- Low cost
- Ruggedness
- Simplicity of construction
- Low maintenance
- Less likely to stall or slip
- Will work in any environment
- Excellent start-stop and reversing responses

# Disadvantages of stepper motors

- Low torque capacity compared to DC motors
- Limited speed
- During overloading, the synchronization will be broken.
- Vibration and noise occur when running at high speed

# Summary

- Stepper motors operate in terms of discrete steps
- They are classified as Variable Reluctance and Permanent Magnet Motors
- They are widely used in position control mechanism