P1- Find the value of I required to establish a magnetic flux of $\Phi = 0.75 \times 10^{-4}\, Wb$ in the series magnetic circuit as shown in the following figure. Calculate the force exerted on the armature (moving part) when flux is established. The relative permeability for the steel is $\mu_r = 1424$.
Note that the energy stored in the air gap is equal to the Volume of the air gap times the magnetic energy density ($W_0 = \frac{B_g^2}{2\mu_0}$). Also, this energy is equal to the Force it can apply to the moving part times the length of the air gap.

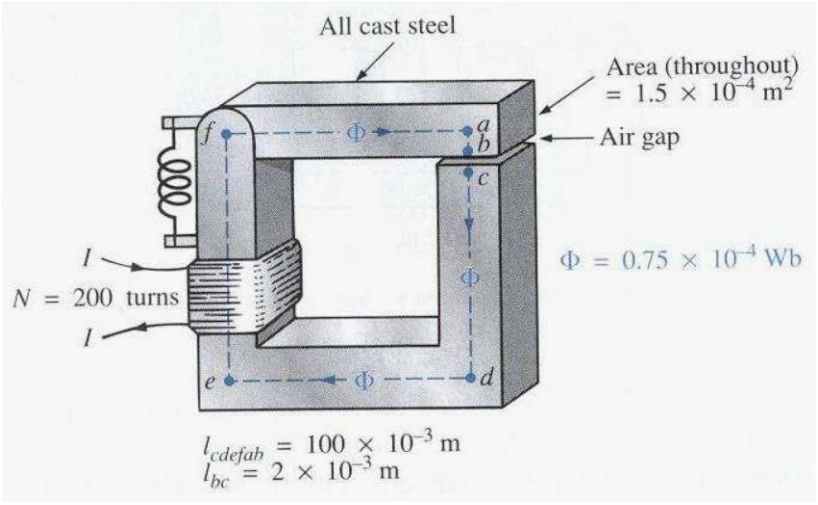

Fig P1.

P2- Determine the value of I required to establish a magnetic flux of $\Phi = 1.54 \times 10^{-4}\, Wb$ in the section of the core indicated in the following figure. The relative permeability for the steel at region *bcde*, *be*, and *efab* are $\mu_2 = 4972$, $\mu_1 = 4821$, and $\mu_2 = 2426$, respectively.

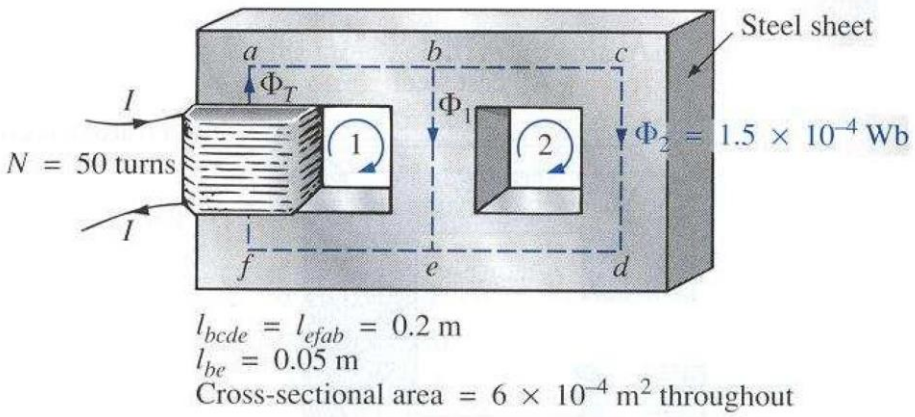

Fig P2.

P3- Consider a stepper motor with three rotor teeth ($n_r = 3$), two stator poles ($n_s = 2$), and two phases ($p = 2$). What is the step angle for this motor in full stepping? Is this a VR motor or a PM motor? Explain.

P4- For a stepper motor with m stator poles per phase, show that the number of teeth in a stator pole is given by

$$t_s = \frac{n}{mp^2} - \frac{1}{p},$$

where n denotes the number of steps per revolution, for the case $n_r > n_s$. Pick suitable parameters for a four-phase, eight-pole motor, using this relation, if the step angle is required to be 1.8^o. Can the same step obtained using a three-phase stepper motor?

P5- The following figure shows a schematic diagram of a stepper motor. What type of stepper is this? Describe the operation of this motor. In particular, discuss whether four separate phases are needed or whether the phases of the opposite stator poles may be connected together, giving a two-phase stepper. What is the step angle of the motor

a. in full stepping?
b. In half stepping?

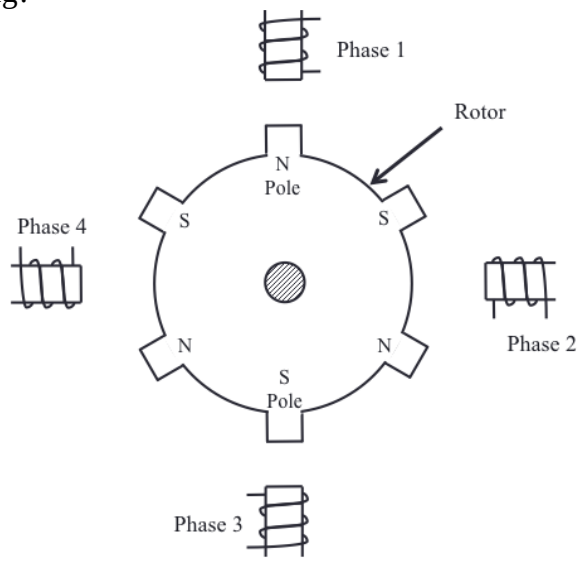

Fig P5.

P6- Using the sinusoidal approximation for static torque in a three-phase variable-reluctance stepper motor, the torques T_1, T_2, and T_3 due to the three phases (1, 2, and 3) activated separately, may be expressed as

$$T_1 = -T_{max} \sin n_r\theta,$$
$$T_2 = -T_{max} \sin(n_r\theta - \frac{2\pi}{3}),$$
$$T_3 = -T_{max} \sin(n_r\theta - \frac{4\pi}{3})$$

where θ is the angular position of the rotor measured from the detent position of phase 1, and n_r is the number of rotor teeth. Using trigonometric identities, show that

$$T_1 + T_2 = -T_{max} \sin(n_r\theta - \frac{\pi}{3}),$$

$$T_2 + T_3 = -T_{max} \sin(n_r\theta - \pi),$$
$$T_3 + T_1 = -T_{max} \sin(n_r\theta - \frac{5\pi}{3}),$$

Using these expressions, show that the step angle for the switching sequence 1-2-3 is $\frac{\theta_r}{3}$ and the step angle for the switching sequence 1-12-2-23-3-31 is $\frac{\theta_r}{6}$. Determine the step angle for the two-phase-on switching sequence 12-23-31.