1.a.(1). Reluctance is directly related to the length of the flux path and inductance is inversely related to length & energy is directly related to inductance, thus energy DECREASES with length, (2) and force acts in a direction to DECREASE the stored energy in the magnetic field [page 134, last paragraph].

b. \( X_d > X_q \) because length of air gap in q axis > than in d axis.

c. \( \mu_{air\_gap} \) is the smallest; \( \mu_{core} \) could be 3 to 4 orders of magnitude higher than for air; from observation of B-H curves, for permanent magnet, B same order of magnitude as the core, but H is several orders of magnitude higher, thus \( \mu_{PM} \) a somewhat higher than air and several orders of magnitude lower than for core material.

2. \( X_d := 1.65 \quad X_q := 1.25 \quad Ia := 1 \quad Va := 1 \quad pf := 0.9 \quad Eafp := Va + Ia \cdot e^{j \cdot \cos(pf)} \cdot Xq \)

\( \delta := \arg(Eafp) \quad \delta = 67.973\text{deg} \quad \phi := \cos(pf) \quad \phi = 25.842\text{deg} \)

\( Id := Ia \cdot \sin(\delta - \phi) \cdot e^{j \left( \frac{\pi}{2} \right)} \quad |Id| = 0.671 \quad \arg(Id) = -22.027\text{deg} \)

\( Iq := Ia \cdot \cos(\delta - \phi) \cdot e^{j \delta} \quad |Iq| = 0.742 \quad \arg(Iq) = 67.973\text{deg} \)

Check: \( |Id + Iq| = 1 \quad \arg(Id + Iq) = 25.842\text{deg} \)

3. \( f_{fld} = \frac{\partial W_{fld}}{\partial X} \quad \text{and} \quad W_{fld} = \frac{1}{2} Li^2 \); therefore, \( f_{fld} = -\frac{K_1K_3}{(K_2 + K_3X)^2} \cdot i^2 \)

4.a. Uniform air-gap, therefore \( L_{an} \) is independent of rotor orientation (\( L_{an} = L_1 \));

salient pole, \( L_{an} = L_2 - L_3 \cos(2\theta_0) \) where \( L_2 > L_3 \) \([\theta_0 = 0^0 \& 180^0, L_{an} \at \min, \theta_0 = 90^0 \& 270^0, L_{an} \at \max]\)

b. When \( i_c = 0 \& di/dt > 0, i_b = 0.866 \) and \( i_a = -0.866 \); therefore phase b flux directed along pos b-b’ axis and phase a flux directed along neg a-a’ axis; resultant \( @ 150^0 \).

5. \( X_d := 0.78 \quad X_q := 0.63 \quad Va := 1.6 \quad Eaf := 1.6 \quad \delta := 16.5 \quad \phi := 90^0 \)

\( P_{cyl} := \frac{Vb^2 \cdot (Xd - Xq)}{2 \cdot (Xd \cdot Xq)} \sin \left( \frac{\delta \cdot \pi}{180} \right) \quad P_{reruct} := \frac{Vb^2 \cdot (Xd - Xq)}{2 \cdot Xd \cdot Xq} \sin \left( \frac{2 \cdot \delta \cdot \pi}{180} \right) \)

\( P_{cyl} = 0.596 \quad P_{reruct} = 0.085 \quad P_{salient} := P_{cyl} + P_{reruct} \quad P_{salient} = 0.681 \)

Bonus: CCW, NO, CCW