4–2 A three-phase four-pole winding is installed in 12 slots on a stator. There are 40 turns of wire in each slot of the windings. All coils in each phase are connected in series, and the three phases are connected in Δ. The flux per pole in the machine is 0.060 Wb, and the speed of rotation of the magnetic field is 1800 r/min.

a. What is the frequency of the voltage produced in this winding?

b. What are the resulting phase and terminal voltages of this stator?

a) Use (4-23), $f_e = \dfrac{n_m P}{120}$ where n_m is the magnetic field rotation speed (RPM), f_e is the electrical frequency (Hz), and P is the number of poles.

$$f_e = \frac{1800(4)}{120} \quad \Rightarrow \quad \underline{\boldsymbol{f_e = 60\ (\text{Hz})}}$$

b) Use (4-39), $E_A = \sqrt{2}\,\pi N_C \phi f$ where N_C is the turns of wire, ϕ is the magnetic flux (Wb), and f is the electrical frequency (Hz) to get the voltage for one pair of slots, i.e., one coil.

$$E_A = \sqrt{2}\,\pi N_C \phi f = \sqrt{2}\,\pi(40)0.06(60) \quad \Rightarrow \quad \underline{E_A = 639.775\ (\text{V}_{\text{rms}})/(2\ \text{slots or coil})}.$$

With 12 slots on the stator, we would have 12 slots/ 3 phases = 4 slots per phase.

In turn, this means we have 4 slots per phase / 2 slots per coil = 2 coils per phase.

The phase voltage is then

$$V_\phi = (2\ \text{coils})\ 639.775\ /\ \text{coil} \quad \Rightarrow \quad \underline{\boldsymbol{V_\phi = 1279.55\ (\text{V}_{\text{rms}})}}.$$

Per (2-14), $V_T = V_{LL} = V_\phi$ for a Δ-connection $\Rightarrow$ $\underline{\boldsymbol{V_T = 1279.55\ (\text{V}_{\text{rms}})}}$.