In the figure below right, a 200-turn coil of radius 2.0 cm and resistance 5.0 Ω is coaxial with a solenoid of 250 turns/cm and diameter 3.0 cm. The solenoid current increases from zero to 3.0 A in time interval $\Delta t = 15$ ms. The direction of the current is shown in the figure.

a) What are the magnitude and direction of the magnetic field inside the solenoid at the end of time interval $\Delta t$? (To show the direction, draw an arrow in the figure.)

At the end of $\Delta t$, the current is $I = 3$ A. The number of turns per unit length of the solenoid is $n = 25000$ turns/m in SI unit. The magnitude of the magnetic field inside of the solenoid is

$$B_f = \mu_0 n I = 9.42 \times 10^{-2} \text{T}$$

Curl your fingers in the direction of the current, then your thumb points in the direction of the magnetic field. The field is to the right.

b) What average current is induced in the coil during $\Delta t$?

The magnetic field exists only inside the solenoid. Therefore, the magnetic flux through the coil at the end of $\Delta t$ is

$$\Phi_f = B_f A_c = B_f (d/2)^2 = 6.66 \times 10^{-5} \text{ Wb}$$

At the beginning of $\Delta t$, the flux is zero because the current in the solenoid is zero. We apply Faraday’s law to obtain the magnitude of the emf induced in the coil:

$$\epsilon_{\text{ind}} = N \Delta \Phi / \Delta t = N (\Phi_f - \Phi_i) / \Delta t = 0.888 \text{ V}$$

Ohm’s law leads to

$$I_{\text{ind}} = \epsilon_{\text{ind}} / R = 0.178 \text{ A}$$

c) What is the direction of the current induced in the coil? (Just draw $*$ and $\times$ in the figure.)

The magnetic flux is to the right and it is increasing. According to Lenz’s law, the induced current must oppose this change, meaning the magnetic field due to the induced current must be to the left. Point your extended thumb to the left, then your fingers curls in the direction of the induced current. The direction of the induced current is shown in the figure.