1. The cross-sections of two hollow infinitely long cylindrical conductors are shown in blue and red in Fig. 1. The blue cylindrical conductor carries a constant current, I_{12}, out of the page, with uniform current density J_{12}. The red cylindrical conductor carries a current into the page, with current density $J_{34} = \frac{3J_{12}r}{2}$.

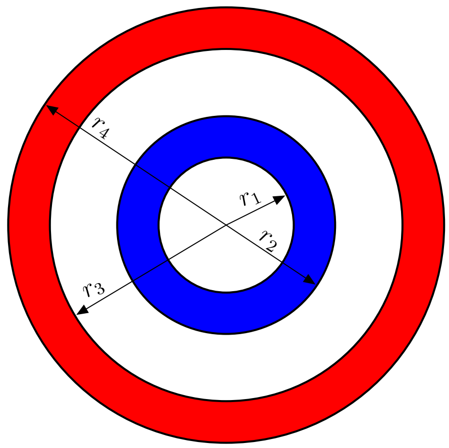

Figure 1: The cross-sections of two hollow infinitely long cylindrical conductors are shown in blue and red. The blue cylinder has inner radius r_1 and outer radius r_2. The red cylinder has inner radius r_3 and outer radius r_4.

(a) Find the magnitude of the magnetic field at a distance r, $r_1 < r < r_2$, from the axis.

Ans: $B = \frac{\mu_o I_{12}}{2\pi r}\left(\frac{r^2 - {r_1}^2}{{r_2}^2 - {r_1}^2}\right)$.

(b) Find the magnitude of the magnetic field at a distance r, $r_3 < r < r_4$, from the axis.

Ans: $B = \frac{\mu_o I_{12}}{2\pi r}\left|1 - \frac{r^3 - {r_3}^3}{{r_2}^2 - {r_1}^2}\right|$.

2. A blue wire is wound evenly on a torus of rectangular cross section, see Fig. 4. Find the self inductance of this torus.

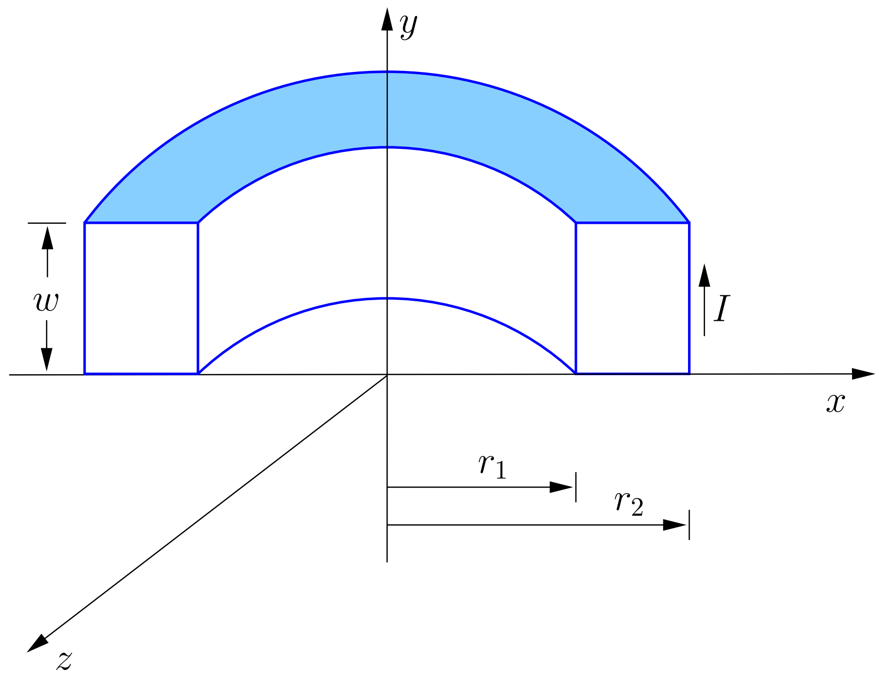

Figure 4: A blue wire is wound evenly on a torus of rectangular cross section, with inner radius r_1 and outer radius r_2. There are N turns of the blue wire in all.

Ans: $L = \frac{\mu_o N^2 w}{2\pi} \ln\left(\frac{r_2}{r_1}\right)$.

3. A blue wire carrying current I is wound evenly on a torus of rectangular cross section. There are N turns of the blue wire in all. A red wire is thrown over the torus and is connected to a resistor, R, see Fig. 5. Find the mutual inductance of this arrangement.

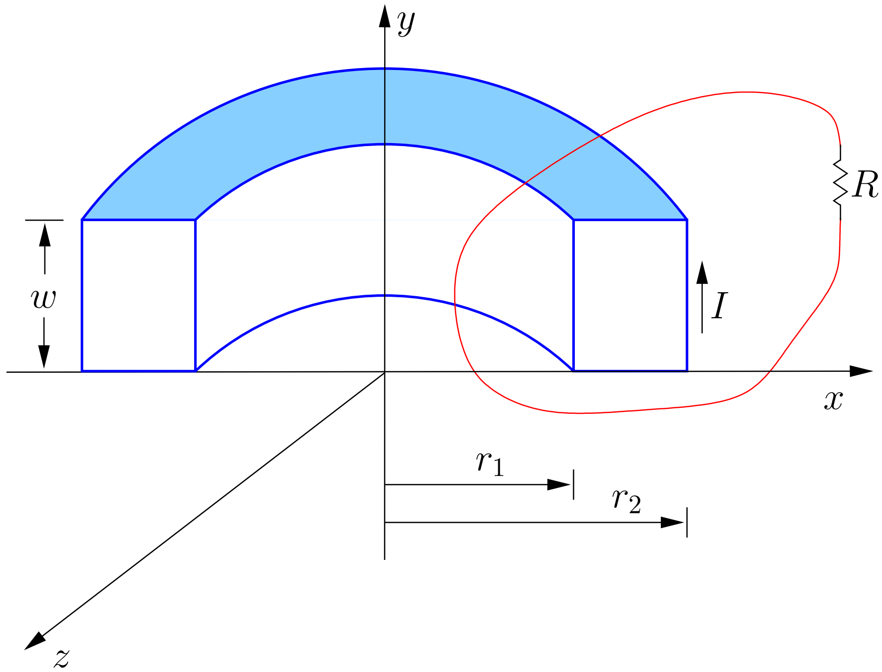

Figure 5: A blue wire carrying current I is wound evenly on a torus of rectangular cross section, with inner radius r_1 and outer radius r_2. There are N turns of the blue wire in all. A red wire is thrown over the torus and is connected to a resistor, R.

Ans: $M = \frac{\mu_o N w}{2\pi} \ln\left(\frac{r_2}{r_1}\right).$

4. Consider the circuit shown in Fig. 6.

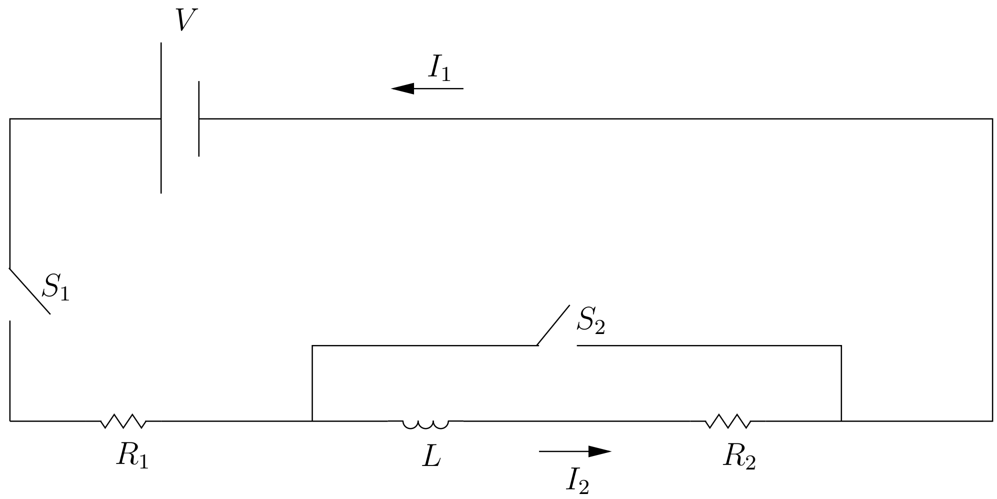

Figure 6: An LR circuit is shown.

(a) At time $t = 0$, switch S_1 is closed and switch S_2 is left open. Find current I_1 as a function of time.
Ans: $I_1 = \frac{V}{R_1+R_2}\left(1 - e^{-\frac{R_1+R_2}{L}t}\right)$.

(b) Find current I_1 after a very long time.
Ans: $I_1 = \frac{V}{R_1+R_2}$ at $t = \infty$.

(c) After the current in the circuit has reached its final, steady-state value with switch S_1 closed and S_2 open, switch S_2 is closed, thus short-circuiting the inductor. (Switch S_1 remains closed.) Find current I_1.
Ans: $I_1 = \frac{V}{R_1}$.

(d) Find current I_2 as a function of time t that has elapsed since S_2 was closed.
Ans: $I_2 = \frac{V}{R_1+R_2}e^{-\frac{R_2}{L}t}$.