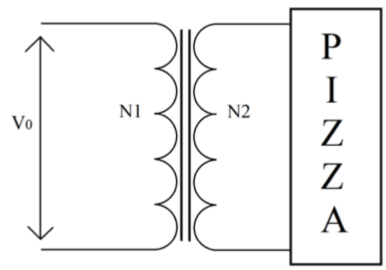
General Physics: Electromagnetism, Problem Set 12

Exercise 1 :

A neon signs requires a voltage of $V_2 = 12$ kV to operate. Given an input of $V_0 = 240$ V from a power line, a transformer is used to achieve the necessary voltage. What should be the ratio of the number of turns in the secondary winding to the number of turns in the primary winding of the transformer? What would be the output voltage if the transformer was connected in reverse?



Exercise 2 :

A coaxial cable of length l is made of a central conductive wire of radius r_1 and the surrounding tube-like outer conductor of radius r_2 ($r_1 \ll r_2 \ll l$), separated by a dielectric tube (see Figure below). These cables are widely used for transmitting high-frequency signals with the two conductors of the cable on one end connected to a source and on the other end connected to a receiver. Determine the self inductance L of such cable.

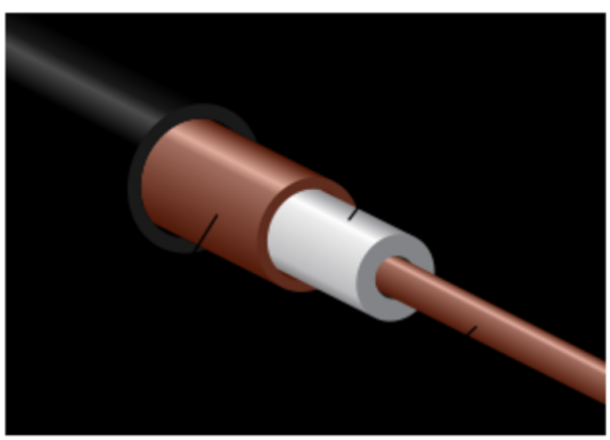


Figure 1: Coaxial cable.

Exercise 3 :

Consider a long cable that consists of two parallel straight round wires of length l, diameter $2a$, made of non-magnetic conductive material (see Figure below). The centers of the wires in the cables are separated by distance D, such that: $l \gg D \gg 2a$. When such a cable is used, the directions of the current in the wires are opposite. Derive an expression for self inductance L of the cable.

Hint: To compute the flux, consider a closed loop obtained by connecting with small conductive wires both the extremities of the two different cables. Since these two extra wires are small, you can assume they do not change the self inductance of the two wires. Remember that for calculating the self inductance of a circuit, you have to consider the magnetic flux through the circuit generated by the current flowing in the circuit. Since $D \gg a$, you can neglect the contribution of the magnetic flux through the wires themselves.

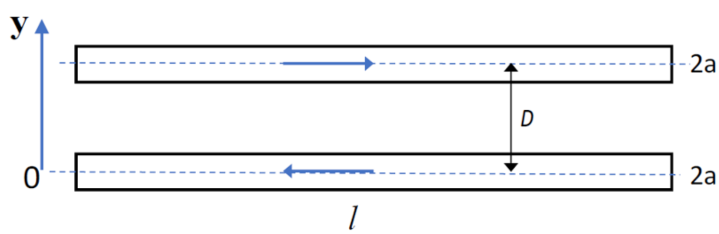


Figure 2: Two wires at distance D.

Exercise 4 :

Two ideal solenoids are made of two pieces of wire of the same thickness $t = 1$ mm but different lengths. Solenoids are tightly wound without gaps between the coils. The larger solenoid of diameter $D_1 = 4$ cm is made from the wire of the length $L_1 = 8$ m, and the smaller solenoid of diameter $D_2 = 2$ cm is made from the wire of the length $L_2 = 2$ m. Note, that this these are not the lengths of the solenoids, but the lengths of the wires used to make them. The smaller solenoid is fully inserted into the larger one. Determine the mutual inductance of the two solenoids M_{21}. $\mu_0 = 4\pi \cdot 10^{-7}$ H/m.

Exercise 5 :

Figure 3 shows a coil of N_2 turns and radius R_2 surrounding a long solenoid of length l_1, radius R_1, and N_1 turns.

1. What is the mutual inductance of the two coils?

2. If $N_1 = 500\,\text{turns}$, $N_2 = 10\,\text{turns}$, $R_1 = 3.10\,\text{cm}$, $l_1 = 75.0\,\text{cm}$, and the current in the solenoid is changing at a rate of $200\,\text{A/s}$, what is the emf induced in the surrounding coil?

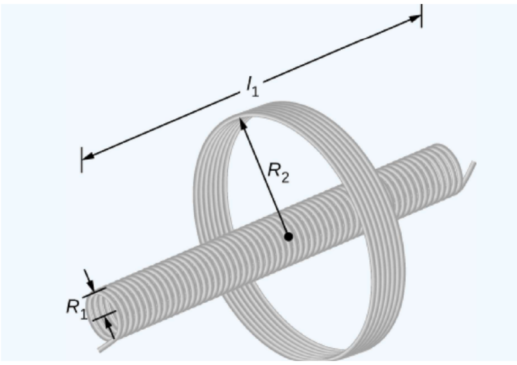


Figure 3: A solenoid surrounded by a coil.

Exercise 6 :

Figure 4 shows two long, concentric cylindrical shells of radii R_1 and R_2. This configuration is a simplified representation of a coaxial cable. The capacitance per unit length of the cable has already been calculated.

1. Determine the magnetic energy stored per unit length of the coaxial cable, and
2. Use this result to find the self-inductance per unit length of the cable.

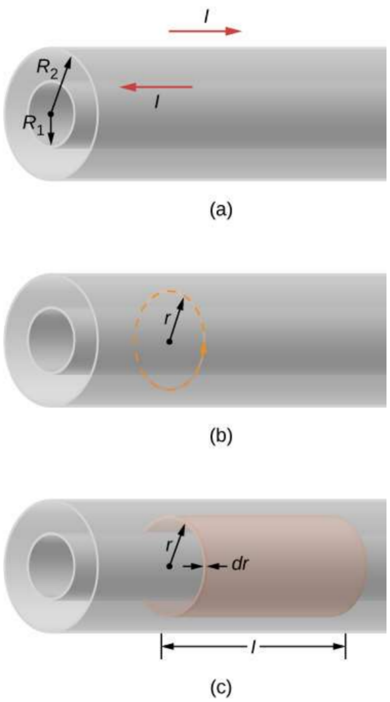


Figure 4: (a) A coaxial cable is represented here by two hollow, concentric cylindrical conductors along which electric current flows in opposite directions. (b) The magnetic field between the conductors can be found by applying Ampère's law to the dashed path. (c) The cylindrical shell is used to find the magnetic energy stored in a length l of the cable.