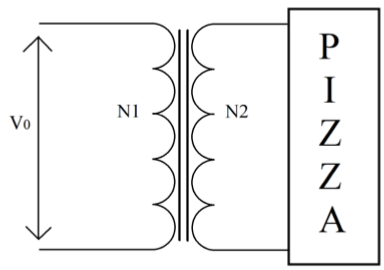
General Physics: Electromagnetism, Problem Set 11

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.

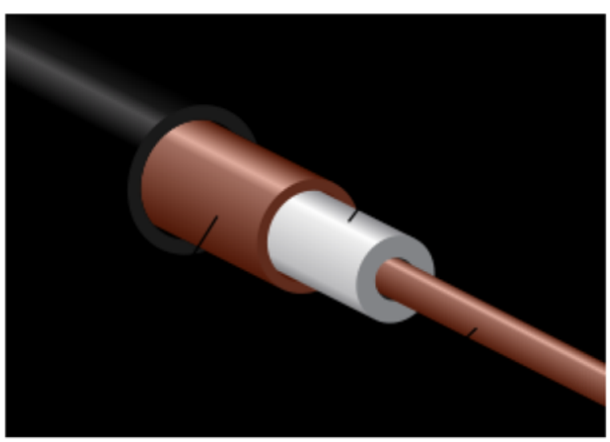


Figure 1: Coaxial cable.

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.

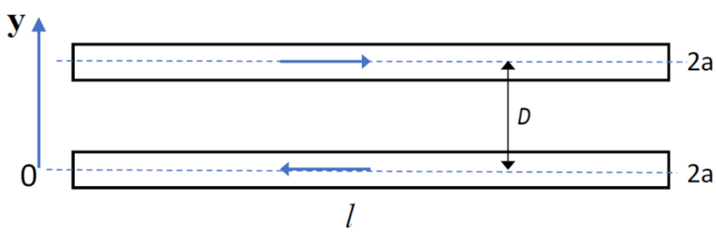
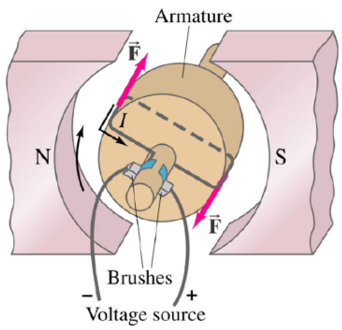


Figure 2: Two wires at distance D.

Exercise 4 :

A small electric car experiences a frictional force of 250 N when moving at a constant speed of 35 km/h. The electric motor is powered by ten batteries of 12 V each, connected in series. It contains a rectangular coil with 270 turns and of size 12×15 cm, which rotates in a magnetic field $B = 0.6$ T. The motor is directly connected (without gearbox) to the wheels with a diameter of 58 cm, so the coil and the wheels turn at the same frequency. We consider the moment when the coil is in the same plane as the magnetic field $\vec{B}$, such that the generated torque is maximal.

1. What is the current passing through the motor?
2. What is the emf induced in the coil?
3. What is the dissipated power in the coil?
4. What percentage of power produced by the motor is delivered to the wheels?



Exercise 5 :

A square conductive loop with side length $l = 10\,\text{cm}$ and total resistance $R = 10\,\Omega$ is immersed in a uniform magnetic field $B = 0.52\,\text{T}$. The loop is constrained to rotate about a fixed axis orthogonal to the direction of the field, as shown in the figure below. Let θ be the angle between the direction of the magnetic field and the normal to the loop. The loop is kept in rotation with a constant angular velocity $\omega = 12.4\,\text{rad/s}$.

Determine:

(a) the absolute value of the electric charge passing through the loop during half a turn between the positions $\theta = 0$ and $\theta = \pi$;

(b) the external mechanical torque required to maintain the loop in rotation, and its average value over one turn;

(c) the work done by this mechanical torque over one turn. Remember that the work done by a torque τ is given by $W = \int_{\theta_1}^{\theta_2} \tau d\theta$, where θ_1 and θ_2 represent the initial and final angular positions.

(d) the energy dissipated in the loop over one turn.

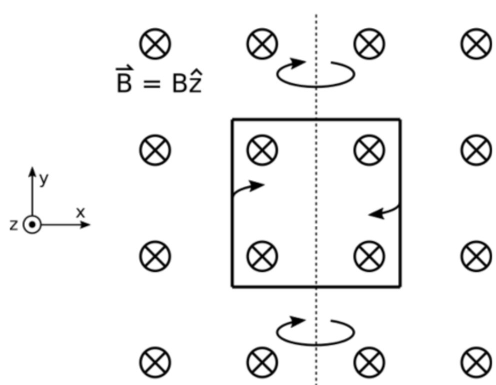


Figure 3: Square conducting loop in magnetic field