Exam-03

1. Consider an open-circuit coil, located in air, with N = 500 windings, having a square-shaped opening with side length ℓ = 0.2 m. The coil is oriented so that it lies in the plane y = 0. Assume no magnetic field for $x < 0$ and a field $\vec{H}$ = 100 A/m directed along the +y-direction for $x > 0$.
   (a) Draw an x, y, z coordinate system, the plane y = 0, coil, and magnetic field. Label all objects.
   (b) The coil is now moved along the x-axis at a velocity of v = 0.1 m/s. Assume that the coil starts to enter the magnetic field at t = 0 s. Calculate the induced voltage for relevant time intervals and draw a diagram of induced-voltage-versus-time. Label all relevant points.
   (c) The square-shaped coil is now replaced by a circular coil with radius r = 0.1 m. For this case, plot the induced-voltage-versus-time-diagram.
   (d) The circular coil is re-oriented so that it lies in the plane z = 0. The coil is moved along the x-axis with a velocity of v = 0.1 m/s. Sketch the experimental setup. Plot the induced-voltage-versus-time-diagram.

2. Consider a wire loop, with N = 100 windings, being square-shaped, with side length ℓ = 50 cm and area $A_0 = \ell^2$, in a constant and uniform magnetic flux density $\vec{B}$ = 0.5 T. In order to generate electricity, the wire loop is forced to rotate at frequency f = 600 rotations per minute = 600 / minute. At t = 0, the magnetic flux that penetrates the area $A(t)$ is maximal.
   (a) Draw the experimental setup at t = 0 and t = 25 ms and label all objects. Express the area $A(t)$ that is penetrated by $\vec{B}$ as a function of time by using A_0 and a cosine function.
   (b) Calculate the voltage that is induced at the two terminals of the wire loop as a function of time. *Hint*: $\frac{\mathrm{d}}{\mathrm{d}t}\Phi_\mathrm{m} = \frac{\mathrm{d}}{\mathrm{d}t}(\vec{B}\cdot\vec{A}) = B\frac{\mathrm{d}}{\mathrm{d}t}A(t)$. Give the amplitude V_0 of the voltage.
   (c) Assume that the wire loop is operated as (i) open and (ii) short circuit (OC & SC). For each case, make a drawing that shows the (i) loop's rotation direction and (ii) direction of the magnetic force F_m acting on the wire loop.

3. A transformer, operated at 60 Hz having a primary coil with N = 500 windings and a secondary coil, uses a soft magnetic core material (negligibly small H_{coercive}), with μ_r = 10 000, forming a magnetic circuit that has a cross-sectional area A = 4 cm^2 and a length of ℓ = 25 cm. The design of the transformer requires that the maximum B-field in the core equals B_{residual} = 2.0 T.
   (a) Draw the experimental setup and label all objects. Calculate the maximum H-field and maximum current I to be used for the primary coil.
   (b) Calculate the maximum magnetic energy stored in the core. Calculate the maximum power that the transformer can transmit from the primary coil to the secondary coil.

4. Determine if the following statements are (i) true, (ii) false, or (iii) impossible to determine due to lack of information. Explain each of your answers with a few words.
   (a) The field lines of the Earth's magnetic flux density $\vec{B}$ have no beginning and no end.
   (b) An electric motor can use (i) a permanent magnet or (ii) an electromagnet to generate the stator's magnetic field. A motor using permanent magnets is usually more energy efficient.