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UNIVERSITY EXAMINATIONS 2022/2023

SECOND YEAR, FIRST SEMESTER SPECIAL/SUPPLEMENTARY EXAMINATION FOR DEGREE OF BACHELOR OF SCIENCE IN MATHEMATICS AND PHYSICS AND BACHELOR OF EDUCATION SCIENCE

SPH 3201: ELECTRICITY AND MAGNETISM II

DATE: AUGUST 2023 **TIME: 2 HOURS**

INSTRUCTIONS: Answer Question ONE and any other TWO questions.

Where necessary use the following constants

Permeability of free space(μ_0)	$4\pi \times 10^{-7} henry/meter$
Permeability of free space (ε_0)	$8.85 \times 10^{-12} C^2.N^{-1}.m^{-2}$
Velocity of light (c)	$3.0 \times 10^8 ms^{-1}$
Mass of electron (m_e)	$9.11 \times 10^{-31} kg$
Mass of proton (m_p)	$1.67 \times 10^{-27} kg$
Charge on an electron	$-1.6 \times 10^{-19} C$
Charge on a proton	$1.6 \times 10^{-19} C$

QUESTION ONE (30 MARKS)

a) An alternating voltage is triangular in shape, rising at a constant rate to a maximum of 300V in 8 ms and then falling to zero at a constant rate in 4 ms. The negative half cycle is identical in shape to the positive half cycle. Calculate (i) the mean voltage over half a cycle, and (ii) the r.m.s voltage (2 Marks)

b) What are the four Maxwell equations in differential form and which law does each represent? (4 Marks)

c) A 50-turn coil has a diameter of 15 cm. The coil is placed in a spatially uniform magnetic field of magnetic 0.50 T so that the face of the coil and the magnetic field are perpendicular. Find the magnitude of the emf induced in the coil if the magnetic field is reduced to zero uniformly in (i) 0.10s, (ii) 1.0s, and (iii) 60 s. (4 Marks)

d) A 200 resistor is connected in series with a 5.0-microF capacitor. The voltage across the resistor is v=(1.20 V)cos(2500 rads/sec)t.

   i. Write an expression for the circuit current (2 Marks)

   ii. Determine the capacitive reactance of the capacitor (2 Marks)

   iii. Derive an expression for the voltage across the capacitor. (2 Marks)

e) The maximum working flux density of a lifting electromagnet is 1.6 T and the effective area of a pole face is circular in cross-section. If the total magnetic flux produced is 353m Wb, determine the radius of the pole face. (3 Marks)

f) Electronic gadgets today use transistors in place of vacuum tubes which were popular in the past. Highlight any three advantages of transistors over vacuum tubes. (3 Marks)

g) A toroidal coil has a mean radius of 16 cm and a cross-sectional area of 0.25 cm 2; it is wound uniformly with 1000 turns. A second toroidal coil of 750 turns is wound uniformly over the first coil. Ignoring the variation of the magnetic field within a toroid, determine the mutual inductance of the two coils. (4 Marks)

h) Starting from Vcc = IcRc + Vce, where the symbols have their usual meanings, obtain equation for a transistor loadline of a CE amplifier and show that it is the equation of a straight. (4 Marks)

QUESTION TWO (20 MARKS)

a) Two 10 cm x 10 cm pieces of aluminum foil of thickness 0.1 mm face each other with a separation of 5mm. one of the foils has a charge of +30μC and the other has -30μC.

   i. Find the charge density at all surfaces, i.e., on those facing each other and those facing away.

   ii. Find the electric field between the plates near the centre assuming planar symmetry. (6 Marks)

b) A resistor with R=850Ω is connected to the plates of a charged capacitor with capacitance $C = 4.62\mu F$. just before the connection is made, the charge on the capacitor is 6.90Mc

i. What is the energy initially stored in the capacitor?

ii. What is the electrical power dissipated in the resistor just after the connection is made?

iii. What is the electrical power dissipated in the resistor at the instant when the energy stored in the capacitor has decreased to half the value calculated in part (i)? (8 Marks)

c) Two non-conducting spheres of radii R_1 and R_2 are uniformly charged with charge densities $\rho 1$ and $\rho 2$, resepectively. They are separated at center-to-center distance α (Figure 1 below). Find the electric field at point P located at a distance r from the centre of sphere 1 and is in the direction θ from the line joining the two sphere assuming their charge densities are not affected by the presence of the other sphere.

QUESTION THREE (20 MARKS)

a) When a 360-nF air capacitor is connected to a power supply, the energy stored in the capacitor is 18.5 μJ. While the capacitor is connected to the power supply, a slab of dielectric is inserted that completely fills the space between the plates. This increases the stored energy by 23.2μJ.

i. What is the potential difference between the capacitor plates?

ii. What is the dielectric constant of the slab? (6 Marks)

b) A 2.00- and a 7.50-μFcapcitor can be connected in series or parallel, as a can a 25.0- and a 100-KΩ resistor. Calculate the four RC time constants possible from connecting the resulting capacitance and resistance in series. (6 Marks)

c) Consider the circuit shown in figure 2 write equations for the three currents in terms of R and V.

QUESTION FOUR (20 MARKS)

a) The square armature coil of an alternating current generator has 200 turns and is 20.0 cm on side. When it rotates at 3600 rpm, its peak output voltage is 120V.
   i. What is the frequency of the output voltage?
   ii. What is the strength of the magnetic field in which the coil is turning? (6 Marks)

b) Show that for an L-R-C series circuit the power factor is equal to R/Z. (2 Marks)

c) In an RLC series circuit, the voltage amplitude and frequency of the source are 100 V and 500 Hz, respectively, an R=500Ω, L=0.20, and C=2.0μF.
   i. What is the impedance of the circuit?
   ii. What is the amplitude of the current from the source?
   iii. If the emf of the source is given by $v(t) = (100V)\sin 1000\pi t$, how does the current vary with time?
   iv. Repeat the calculations with C changed to $0.20\mu F$. (12 Marks)

QUESTION FIVE (20 MARKS)

a) Consider the circuit in figure 3 below. Find $I1, I2$, and $I3$ when
   i. The switch S is first closed,
   ii. After the currents have reached steady-state values, and
   iii. At the instant the switch is reopened (after being closed for a long time)..

b) In a L-R-C series circuit, R = 300Ω, L= 0.4000H and C = 6.0 x 10^{-8}F. When the ac source operates at the resonance frequency of the circuit, the current amplitude is 0.500 A.

i. What is the voltage amplitude of the sources? (4 Marks)

ii. What is the amplitude of the voltage across the resistor, across the inductor, and across the capacitor? (4 Marks)

iii. What is the average power supplied by the source? (4 Marks)