WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 2nd Semester Examination, 2020

PHSACOR03T-PHYSICS (CC3)

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Answer Question No. 1 and any *two* questions from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) The electrostatic field is given by $\vec{E} = 2axi + byj$. What is the charge density that produces this field?

(b) Show that the function $\phi = 4x^2 + 5y - 4z^2$ can represent the electrostatic potential in a charge free region.

(c) Which one of the following is an impossible magnetic field?

(i) $\vec{B} = 3xi + 5yj - 7zk$; (ii) $\vec{B} = 4xi - 7yj + 3zk$

(d) A series LCR circuit is used in a radio set to tune into an FM station broadcasting at 103.7 MHz. The resistance in the circuit is 10 Ω and the inductance is 2.0 μH. What is the value of the capacitance that should be used in the circuit?

(e) State Thevenin's theorem for a linear network.

(f) A positively charged particle is placed at the origin of the xy plane in a region where there is a non-zero uniform magnetic field B in the $+z$ direction and a non-zero uniform electric field E in the $+y$ direction. Draw the possible trajectory of the particle.

(g) A thin non conducting ring of radius R has a charge Q, uniformly spread out on it. What is the electrostatic potential at a point P, located on the axis of symmetry at a distance x from the centre of the ring?

(h) A spherical capacitor with inner radius a and outer radius b is filled with an inhomogeneous dielectric with permittivity $\epsilon = \frac{\epsilon_0 k}{r^3}$ for $a < r < b$. The outer sphere is grounded and a charge is placed on the inner sphere. Find the capacitance of the system.

(i) What is magnetomotive force? What is its unit?

(j) A $3\,\mu F$ capacitor is connected in series with a $6\,\mu F$ capacitor. If a 300V potential difference is applied across this combination, find the total energy stored in the system.

(k) Show that the quantity CR in an RC circuit has the dimension of time.

(l) An ac generator has a fixed internal impedance $R_g + jX_g$ and is used to supply power to a passive load that has an impedance $R_g + jX_l$, where $j = \sqrt{-1}$. For maximum power transfer, find the value of X_l.

(m) Find the r.m.s. value of the ac voltage represented by

$$e(t) = e_0 \cos\left(\omega t + \frac{\pi}{2}\right) \quad , \quad \text{for } 0 \le \omega t \le \pi$$
$$= 0 \quad , \quad \text{for } \pi \le \omega t \le 2\pi$$

(n) Two very thin spherical shells of radius *d*, made of non-conducting material, each carrying uniformly distributed charge $+Q$, are located at a distance $10d$ from each other. A point charge $+q$ is placed inside one of the shells at a distance $\frac{d}{2}$ from the centre on the line connecting the centres of the two shells. What is the net force on the charge $+q$?

2. (a) Write down Poisson's equation of electrostatics and state its connection with uniqueness theorem. 2

(b) The electric field in a certain region is given by $\vec{E} = 4r^3\hat{r}$. Prove that charge contained in a spherical surface of radius *d*, centred at the origin, is $16\pi\epsilon_0 d^5$. 3

(c) Determine the interaction energy between two electric dipoles of moments $\vec{P}_1$ and $\vec{P}_2$ separated by a distance $\vec{r}$. Hence find the condition for minimum energy. 3+2

3. (a) Calculate the magnetic field $(\vec{B})$ at a point *P* at a large distance *r* from the centre of a small current carrying loop, where *P* lies on the axis of the loop. Assume that the loop is equivalent to a magnetic dipole, placed at the origin, whose field at an arbitrary point $\vec{r}$ can be expressed in the form 4

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{1}{r^3}[3(\vec{m}.\hat{r})\hat{r} - \vec{m}],$$

where $\vec{m}$ is its magnetic dipole moment. Hence find an expression for the magnitude of $\vec{m}$ for the loop.

(b) A small circular conducting loop of radius *a* is located at the centre of a much larger circular loop of radius *b*, resting in the same plane. The larger loop carries an alternating current $I = I_0 \cos\omega t$, where I_0 and ω are constants. Calculate the value of the induced e.m.f. in the smaller loop. 4

(c) Write down Ampere's circuital law inside magnetized materials. 2

4. (a) Starting from Biot-Savart law show that the magnetic field is solenoidal. 2

(b) Find an expression for the work done due to Hysteresis in a ferromagnetic material. 3

(c) Two long parallel wires *A* and *B* are separated by 3cm and carry currents in two opposite directions. The current through each wire is 6A. Calculate the magnetic field midway between these two wires. 2

(d) A coil with inductance L and internal resistance R is connected in parallel to a capacitance C. Find the resonant angular frequency when this combination is connected to an ideal ac source. 3

5. (a) Show that Kirchoff's first law of network analysis is consistent with the principle of conservation of charge and the second law is consistent with the law of conservation of energy. 2+2

(b) In an RC circuit the capacitor is initially charged when the circuit is open. After closing the switch, how much time will be required to dissipate half the energy initially stored in the capacitor? 3

(c) A series LCR circuit consists of a resistance $R = 10{,}000\ \Omega$, an inductance L = 25 mH, and a variable capacitor C. The ac generator supplies a signal with amplitude of 40V and angular frequency of 1000 radians per second. Find the value of C for which the amplitude of the current will be maximum and also find the maximum value. 2+1

N.B. : *Students have to complete submission of their Answer Scripts through E-mail / Whatsapp to their own respective colleges on the same day / date of examination within 1 hour after end of exam. University / College authorities will not be held responsible for wrong submission (at in proper address). Students are strongly advised not to submit multiple copies of the same answer script.*

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