RAMAKRISHNA MISSION VIDYAMANDIRA
(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. THIRD SEMESTER EXAMINATION, DECEMBER 2018
SECOND YEAR [BATCH 2017-20]
PHYSICS (Honours)
Paper : III

Date : 15/12/2018
Time : 11 am – 3 pm
Full Marks : 100

(Use a separate Answer Book for each group)

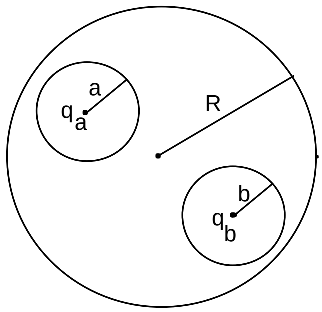
Group – A
Unit-I

Answer **any two** questions from question **nos. 1 to 4**: [2 × 10]

1. a) What do you mean by flux of electric field? How do you identify a field as the electric field? 1+1
   b) A point charge is placed at the centre of a hemispherical bowl. Calculate the electric flux through the surface area of the bowl. 4
   c) A charge Q is spread uniformly in the form of a line charge density $\lambda = \dfrac{Q}{3a}$ on the sides of an equilateral triangle of perimeter $3a$. Calculate the potential at the centroid C of the triangle. What is the electric field at C? 4

2. a) How can you produce an electric dipole? Show that the force $\vec{F}$ on a dipole placed in a non-uniform electric field $\vec{E}$ can be expressed as $\vec{F} = \vec{\nabla}\left(\vec{p}\cdot\vec{E}\right)$ where $\vec{p}$ is dipole moment of the dipole. Also, state the roles of $\vec{E}$ on $\vec{p}$. 1+4+1
   b) A dipole $\vec{p} = p\hat{i}$ is placed at the origin. Another dipole $\vec{p}'$ is placed at $(a,a,0)$. The dipole $\vec{p}$ is fixed but the dipole $\vec{p}'$ can take any orientation. Find the mutual potential energy of two dipoles. What orientation the dipole $\vec{p}'$ will take so that the potential energy is minimum? 3+1

3. a) Show that the potential of a polarized object can be expressed as the sum of potentials produced by volume charge density ρ_b and surface charge density σ_b. 4
   b) Two spherical cavities of radii a and b are hollowed out from the interior of a neutral conducting sphere of radius R as shown in figure. At the centre of each cavity point charges q_a and q_b are placed.
      (i) Find the surface charge densities σ_a, σ_b and σ_R on the surfaces of radius a, b, and R respectively.
      (ii) What is the field outside the conductor?
      (iii) What is the field within each cavity?
      (iv) What is the force on q_a and q_b?



(4 × 1½)

4. a) An uncharged grounded conducting sphere is placed in an uniform electric field. Calculate the field and potential at an arbitrary point $p(r,\theta,\phi)$ outside the sphere with respect to the centre of the sphere. 6

[Assume the solution of Laplace equation if necessary]

b) Consider a grounded conducting plane of infinite extent. A point charge is placed in front of the grounded conducting plane. Calculate the amount of work done in removing the point charge to infinity. 4

Unit-II

Answer **any five** questions from question **nos. 5 to 12** : 5 × 10

5. a) Show mathematically how a circular coil having n turns and cross-sectional area S and carrying current I, can be taken equivalent to a magnetic dipole of moment $\mu = nIS$. 4

b) Find the vector potential due to an infinitely long solenoid carrying current I and having n turns per unit length at a point (i) inside the solenoid and (ii) outside the solenoid. 2+2

c) What is magnetization? A block of iron consists of 8.5×10^{28} atoms/m^3 is placed in uniform magnetic field. If dipole moment per atom is 1.4×10^{-23} A.m^2. Calculate the magnetization. 1+1

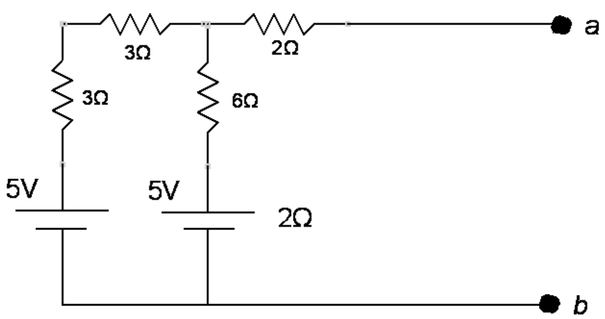
6. a) Starting from the express $\vec{A} = \frac{\mu I}{4\pi}\int \frac{d\vec{l}}{r}$ (symbols have their usual meaning) obtain the expression of $\vec{B}$ for infinitely long straight wire. 4

b) In a medium of $\mu = 4\mu_0$, the magnetic flux density $\vec{B} = y^2\hat{x} + z^2\hat{y} + x^2\hat{z}$ Wb/m^2. (i) Find the magnetic flux through $x = 5m, (0 < y < 1)m, (1 < z < 4)m$, (ii) calculate current density $\vec{J}$ at $(1,1,1)m$. 2+2

c) Find the force per unit length between two parallel wires each carrying 2 Amp current in the opposite direction and placed 5 cm apart. 2

7. a) A circular loop if radius 0.5 m carries current 5 Amp. (i) Find the magnetic field at the centre of the loop, (ii) The loop is placed in a magnetic field of $3\times10^{-5}\,T$. Find the current if work done in rotating the coil through an angle 90°. 2+2

b) State maximum power transfer theorem. Determine the resistance to be connected across a, b, in figure to dissipated maximum power and calculate the maximum power. 2+4

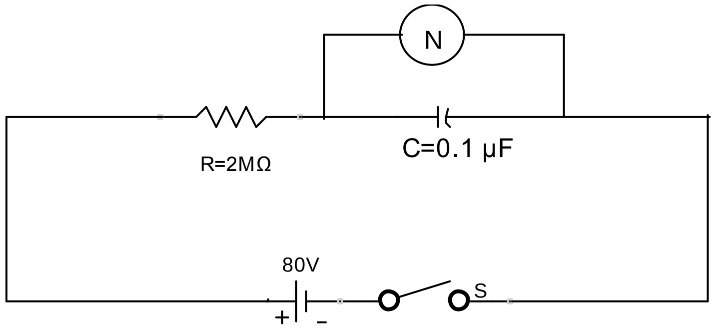


8. a) Show the magnetic energy density u_m within a magnetic material of permeability μ, when placed in a magnetic field H is given by $\mu_m = \frac{1}{2}\int \vec{H}\cdot\vec{B}$. 4

b) Show that the equivalent inductance of two coils of self inductance L_1, L_2 and mutual inductance M connected in parallel is $L_{eq} = \dfrac{L_1L_2 - M^2}{L_1 + L_2 \pm 2M}$. 4

c) A 40 pF air gap capacitor is charged by a 10V battery through a 100Ω resistor. The plates of the capacitor are circular each of area 100 cm^2. At the instant the battery is connected, calculate the conduction current through the capacitor. 2

9. a) In the circuit shown in the figure N is the Neon lamp when the voltage occurs the Neon lamp rises to 40V it glows and becomes conducting but when it becomes just below 40V it is completely extinguished. Find the frequency of flickering if lamp. Assume that the Neon lamp is perfectly insulator when it does not glow. 5



b) How many time constant the energy of a charged capacitor decays to its half value? 2

c) Show that the total energy supplied by the source W_s is equal to the sum of the energy dissipated by the R and the energy stored in L of a series LR circuit. 3

10. a) Show that a uniform magnetisation $\vec{M}$ is equivalent to a bound current density $\vec{K}_m = \vec{M}\times\vec{n}$ (symbols have usual meaning.) 4

b) Establish the continuity relation of magnetic flux. 3

c) A toroid is obtained by winding N = 1000 close turns on an iron core ($\mu_r = 1000$) of mean radius 20 cm and cross-sectional area 10 cm^2. Find the self inductance of the toroid. 3

11. a) Find the magnetic energy (both inside and outside) associated with unit length of an infinitely long straight wire of radius a carrying current I. 4

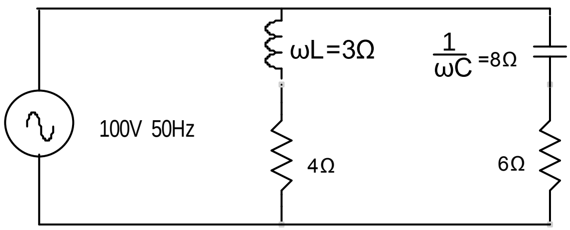
b) The conductors of a coaxial cable with solid inner and thin outer cylinders of radii 2 cm and 5 cm respectively are connected to a battery of emf V and resistance R. Find the self-inductance of the cable per unit length in terms of permeability. 3

c) A square loop of wire of side a lies on a table, at distance s from a very long straight wire, which carries a current I increasing at the rate $\dfrac{dI}{dt}$. (i) Find induced emf in the loop. (ii) What is the direction of the induced current? 2+1

12. a) Obtain an expression for the power factor of an AC circuit. Explain the term “watt less current”. 2+1

b) State disadvantage of phasor. 2

c) Find (i) the impedance of circuit, (ii) the line current, (iii) the power factor and (iv) the power supplied by the ac line. 5



Unit-III

Answer **<u>any one</u>** question from question **<u>nos. 13 & 14</u>** : [1 × 10]

13. a) State Ampere's circuital law. How the law was notified by Maxwell to incorporate the displacement current? 1+2

    b) A 50 pF capacitor is charged to a voltage at the rate 300 V/S. Find the displacement current flowing in the space between capacitor. 3

    c) An alternating current $I = I_0 \sin \omega t$ is flowing through a long straight wire. Find electric field $\vec{E}$, magnetic field $\vec{H}$, Poynting vector $\vec{S}$ and show that the electromagnetic energy flowing into the wire is the Joule's heat. 1+1+1+1

14. a) State and prove Poynting theorem relating the flow of energy at a point in space in an electromagnetic field. 1+4

    b) Consider a charged parallel plate capacitor (neglect the edge effects) immersed in sea-water. The charge on the plates is $q = q_0 \sin 2\pi ft\ C$, where $f = 10^8\,Hz$. At this frequency sea-water has permittivity $\in = 80 \in_0$, permeability $\mu = \mu_0$ and resistivity $\rho = 0.25\Omega m$. Compare the amplitude of conduction and displacement currents. 3

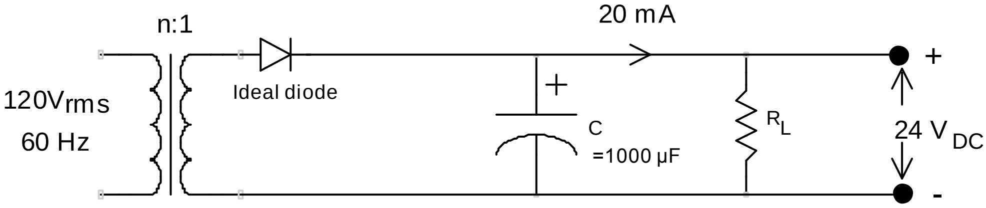
    c) A plane electromagnetic wave in free space has its magnetic field amplitude $2\times10^{-6}T$. Find the magnitude of the Poynting vector. 2

<u>Group – B</u>

Answer **<u>any two</u>** questions from question **<u>nos 15 to 18</u>** : [2 × 10]

15. a) Consider a silicon pn-junction diode with ideality factor 1.4. It is noted that the diode current $I_D = 15mA$ for a diode voltage $V_D = 0.75$ V at room temperature. Calculate the values of diode current for diode voltages 0.80 V and –0.3 V respectively at room temperature. 3

    b) The following circuit converts 120 V (rms), 60 Hz voltage to 24 V DC, with 20 mA of dc current. Find (i) turns ratio of the transformer, (ii) R_L, equivalent load resistance, (iii) peak-to-peak ripple voltage. 4



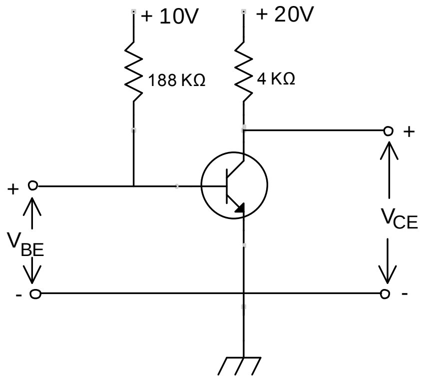
    c) Distinguish between Zener breakdown and avalanche breakdown in a p–n junction diode. What feature of zener diode acts as voltage regulator? 1+2

16. a) The metal lead of the *n*-side of a pn diode is soldered to the metal lead of the *n*-side of another pn diode. Will the structure form an pnp transistor? If not, then explain why. 2

b) Draw the energy band diagram of an open-circuited npn transistor. How is the energy band modified when the transistor is operated in the active region? 2

c) Explain the current amplification factors α and β for *CB* and *CE* configurations, respectively of a pnp transistor. Obtain a relation between them. 3

d) A transistor is operating in the *CE* mode, as shown in the following figure. Calculate V_{CE} if $\beta = 100$, assuming V_{BE} = 0.6 V. Also, determine the region (active / cut-off / saturation) of operation of the transistor in the given circuit 3



17. a) What are the factors that affect the bias stability of a BJT? What impact do they have on the bias stability of the BJT? Explain. 1+2

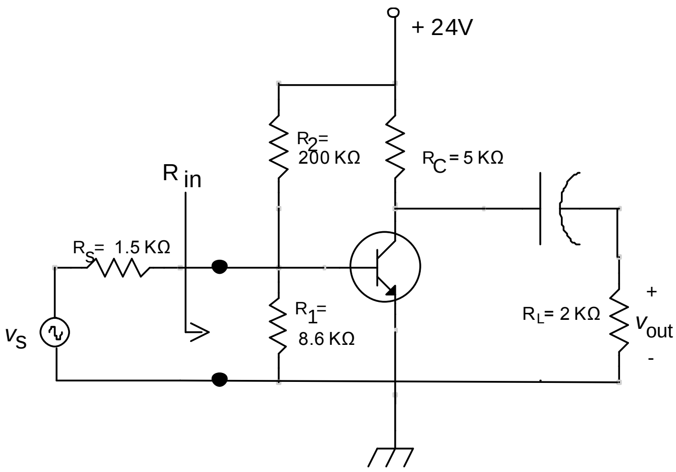
b) Draw the input and output characteristics curve for a transistor (pnp or npn) in CB configuration and define different parameters. 2+1

c) The following circuit shows a transistor amplifier biased to operate as a small signal amplifier. 4

(i) Draw the dc bias circuit and solve for the base and collector dc currents and the dc voltage from collector to emitter.

(ii) Draw the small signal equivalent circuit and solve for the voltage gain of the amplifier, v_{out} / v_s . Consider the capacitors as short circuits at the signal frequency. Let input impedance of the transistor, $r_\pi = 750\Omega$.

(iii) Find the input impedance (R_{in}) of the amplifier as seen by the input generator. This does not include the 1.5 KΩ source resistance.



18. a) "A BJT is a current controlled device while a FET is a voltage controlled device." – Explain. 2

b) What type of gate voltage is necessary to cause current flow in an *n*-channel enhancement MOSFET and to stop current flow in a *p*-channel depletion MOSFET respectively? 2

c) Draw and explain the typical volt-ampere drain characteristics of an *n*-channel depletion mode MOSFET. 3

d) An *n*-channel JFET gives a saturation voltage $V_{D,sat} = 4$ V for $V_{GS} = -1$ V and another one gives $V_{D,sat} = 6.5$ V for same V_{GS}. Compare the pinch-off voltages of the two JFETs. 3

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