2021

PHYSICS — HONOURS

Third Paper

Full Marks : 100

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Question no.* 1** is compulsory. Answer ***any eight questions taking ***four*** from each **unit**.

1. Answer ***any ten*** questions : 2×10

(a) What is a multiplexer? Draw its 4 to 1 circuit diagram.

(b) The modulation index of an FM wave is 10 and the highest modulation frequency is 20 KHz. Find the minimum bandwidth required for the detection of the FM wave.

(c) Build half adder with minimum number of NAND gates.

(d) Write the integral form of Faraday's law and hence show that $\bar{\nabla}\times\bar{E}=-\frac{\partial\bar{B}}{\partial t}$.

(e) An AC circuit connected to a 220V, 50 Hz supply contains a 20H coil of resistance 100 Ω, connected in series with 1 μF capacitor. Calculate the power factor of the circuit.

(f) What is series resonant circuit and why is it called acceptor circuit?

(g) The potential in a region is expressed as $\phi = 2\beta(x^2 + y^3 + z)$. Calculate the charge density in this region.

(h) A pure dipole '*p*' is placed at the origin, pointing in the *z*-direction. Find the force on a point charge *q* at $(a, 0, 0)$.

(i) Define dielectric susceptibility of a medium. What is non-linear dielectric?

(j) A single slit, illuminated by a red light of $6500\,\mathring{A}$, gives first-order Fraunhofer diffraction minima that have angular distances of $\theta = 5^\circ$ from the optic axis. How wide is the slit?

(k) What is meant by 'missing order' in a double slit diffraction pattern?

(l) State Brewster's law.

Unit - 5

2. (a) Define the quantity *Common Mode Rejection Ratio* (ρ) for a Differential Amplifier.

(b) For a Differential Amplifier if v_1 and v_2 are the input signals, then show that the output signal v_o is given by :

$$v_o = A_d v_d(1 + v_c / \rho v_d),$$

where v_d is the difference voltage and v_c is the common mode signal and A_d is the gain of the differential Amplifier.

(c) Draw an analog circuit using OPAMP to solve the following simultaneous equations :

(i) $5x + 2y = 12$ (ii) $2x + 3y = 6$

(d) Show that the negative feedback improves the stability of an amplifier. 1+3+3+3

3. (a) Why negative resistance is provided in an oscillator?

(b) Draw the circuit diagram of a tuned-collector oscillator and write the expression for the frequency of oscillation.

(c) State why *crystal oscillators* are superior for high frequency stability over *LC oscillators*.

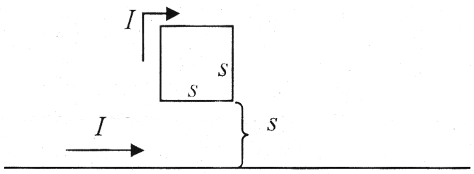
(d) Draw the circuit of an astable multivibrator using transistors. Draw the waveforms at the collector of any one transistor. 2+(2+1)+2+(2+1)

4. (a) Draw a clocked S-R flip-flop circuit using two-input NAND gates and explain its operation with proper truth table.

(b) Distinguish between combinational and sequential logic circuits.

(c) Draw the circuit diagram of a 4-bit ripple counter using 4JK flip-flops (FF). Explain its working. (2+3)+2+3

5. (a) Find the force on a square loop placed as shown in the following figure near an infinite straight wire. Both the loop and the wire carry steady current *I*.



(b) Show that the magnetic field at a large distance ($\bar{r}$) due to a small current loop having magnetic moment $\bar{m}$ is given by

$$\bar{B}(\bar{r}) = \frac{\mu_0}{4\pi}\left[-\frac{\bar{m}}{r^3} + \frac{3(\bar{m}\cdot\bar{r})\bar{r}}{r^5}\right]$$

(c) Magnetic vector potential is given by $\bar{A} = e^{-x}\sin y\hat{i} + (1+\cos y)\hat{j}$. Calculate the magnetic induction. 3+4+3

6. (a) Show that the energy of a magnetic dipole in a magnetic field $\vec{B}$ is given by $U = -\vec{m}\cdot\vec{B}$.

(b) Plot the variation of relative permeability of a magnetic material with magnetic field intensity during magnetization. Explain the nature of plot. How can a material be demagnetized from its initial state of magnetization? Explain with the help of hysteresis loop.

(c) Two magnetic media are separated by a plane interface. Show that the angles between the normal to the boundary and the $\vec{B}$ fields on either side satisfy $\mu_2 \tan\theta_1 = \mu_1 \tan\theta_2$ [symbols having usual meaning]. 3+4+3

7. (a) A circular loop of wire, with radius R, lies in xy-plane, centered at the origin and carries a current I running counterclockwise as viewed from the positive from the positive z axis.

(i) What is the magnetic dipole moment?

(ii) What is its (approximate) magnetic field at points far from the origin?

(b) Determine the self inductance of a co-axial cable.

(c) Show the equivalent inductance of two inductances joined in parallel is given by

$$L_{eqv} = \frac{L_1 L_2 - M^2}{L_1 + L_2 \mp 2M}$$

(1+2)+3+4

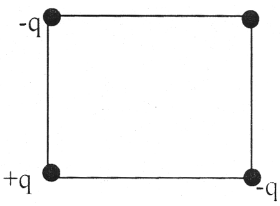
Unit - 6

8. (a) Two charges of charge $+q$ and $-q$ are situated at the location $(a, 0, 0)$ and $(-a, 0, 0)$. If a large conducting plane is placed above at $z = a$, then calculate the net force on $+q$ charge.

(b) Show that the dipole moment of a charge distribution is independent of the choice of the origin if the total charge vanishes.

(c) Three charges are situated at the corners of a square (side a) as shown in the figure below. How much work does it take to bring another charge, $+q$, from far away and place it in the fourth corner?

4+3+3



9. (a) Find the electric field at a distance z above the midpoint of a straight line segment of length $2L$, which carries a uniform line charge λ. Show that, for points far from the line, the line 'looks' like a point charge $q = 2\lambda L$.

(b) Which one of the following is an impossible electrostatic field?

(i) $\vec{E} = k[xy\hat{x} + 2yz\hat{y} + 3xz\hat{z}]$

(ii) $\vec{E} = k[y^2\hat{x} + (2xy + z^2)\hat{y} + 2yz\hat{z}]$

(c) Spherical charge distribution has been expressed as :

$$\rho = \rho_0(1 - r^2/a^2) \quad \text{for } r \le a$$
$$= 0 \quad \text{for } r > 0$$

Find the electric field intensity and potential inside ($r < a$) the charge distribution. (3+1)+2+4

10. (a) Find the general solution to Laplace's equation in spherical coordinates, for the case where the potential, V depends on r only.

(b) Prove, by the method of boundary condition, that the field inside a spherical cavity in an isotropic dielectric is given by : $E_i = E + (P / 3\varepsilon_0)$,
where the symbols have their usual meaning.

(c) Show that the electric field produced by a polarized dielectric can be given by the contributions from a bound charge density $\sigma = \vec{P} \cdot \hat{n}$ and a volume charge density $\rho = -\vec{\nabla} \cdot \vec{P}$. 2+4+4

11. (a) Show that, in two dimensions the shape of the fringes produced in Young's experiment is hyperbolic.

(b) Cite one example / experiment for the each following type of interferometers :

(i) Wavefront-splitting interferometer (ii) Amplitude-splitting interferometer.

(c) A soap film of refractive index 1·33 and of thickness 1·4 μm is illuminated by white light falling at an angle of 60°. The light reflected by it contains a dark band corresponding to wavelength of 5000Å. Determine the order of interference dark band.

(d) Why a broad source of light is necessary for observing colours in thin film? 3+2+3+2

12. (a) Derive an expression for the intensity of Fraunhofer diffraction pattern for a double slit.

(b) Starting from the grating equation, find an expression describing the angular spread for a small range of wavelengths, $\Delta\theta / \Delta\lambda$, i.e., the dispersive power D. Then compute the dispersive power in the first and second orders for a grating with 1500 groves per inch operating in the visible region.

(c) Consider a grating with slit of width a = 0·001 mm, separated by a distance of 0·002 mm. How many orders would be visible at λ = 500 nm? 4+(1+2)+3

13. (a) What is optical activity? Give Fresnel's explanation of rotation of plane of polarisation by an optically active substance.

(b) An unpolarized beam strikes the surface of a pond. Find out the angle of incidence, so that the reflected beam will be completely polarized with its E-field perpendicular to the plane of incidence. Given : Refractive index of the pond water : 1·33. Derive the formula you use.

(c) Explain the phenomenon of double refraction in a uniaxial crystal by applying Huygen's theory.
4+(2+2)+2

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