2022

PHYSICS — HONOURS

Paper : CC-13

(Syllabus : 2019-2020)

[Digital Systems and Applications]

Full Marks : 50

The figures in the margin indicate full marks.

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

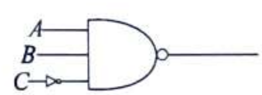
Answer ***question no.* 1** and ***any four*** from the rest.

1. Answer ***any five*** questions : 2×5

(a) Convert 45·625 into its binary equivalent.

(b) Subtract $(1011)_2$ from $(1101)_2$ using 2's complement method.

(c) Determine the output expression for the following circuit and simplify it.



(d) Implement the boolean expression $X = AB + \overline{A}C$ using NAND gates only.

(e) What is the basic difference between a S-R Flip-Flop and J-K Flip-Flop?

(f) Design a NOT-gate using a transistor ($\beta_{sat} = 50$) considering $V_{CE\ sat} = 0{\cdot}2V$, $I_C = 5$ mA and source voltage 5 volt.

(g) What is inequality detector?

2. (a) Simplify the following Boolean expression in SOP form using Karnaugh Map.

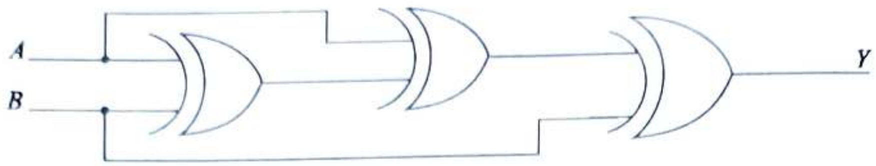
$F(A, B, C, D) = \sum m\,(0, 1, 2, 5, 8, 9, 10)$

(b) Implement the above simplified expression using basic gates.

(c) Make the truth table for the logical function

$f = AB + A\overline{C} + C + AD + A\overline{B}C + ABC$

(d) Write down the Boolean expression for the output (Y) of the following circuit.



3+2+3+2

3. (a) Design a 8 : 1 multiplexer using two 4 : 1 multiplexers.

(b) Implement the following Boolean expression using 8 : 1 multiplexer.

$$F(A, B, C) = \sum m\,(2, 4, 6, 7)$$

How can you use a 8 : 1 multiplexer to implement a logical expression with four inputs?

(c) Write down the basic difference between decoder and de-multiplexer. 3+(3+2)+2

4. (a) Draw the circuit diagram of J-K Flip-Flop and explain its operation using sequence table.

(b) Implement a D-Flip-Flop using J-K Flip-Flop.

(c) Draw the full adder circuit using NAND gate only. (2+3)+2+3

5. (a) What is the basic difference in operation between MS-JK and JK Flip-Flop? Explain with block diagram.

(b) Why is J-K Flip-Flop called an one-bit register? Explain the utility of preset and clear operation in Flip-Flop in this regard.

(c) What is the difference between positive and negative edge triggering? Which type of triggering can be implemented using these triggering? (2+2)+(2+2)+(1+1)

6. (a) What are the differences between Synchronous and Asynchronous counters?

(b) What is shift register? Draw a circuit diagram of a 4-bit shift register.

(c) For 4-bit data transmission, what is the time required if we use SISO and SIPO shift register? Given the duration of each of the clock pulse is 2 ms. 2+(2+3)+3

7. (a) Draw the block diagram of D/A conversion circuit.

(b) A five-bit D/A converter produces $V_{out} = 0{\cdot}2V$ for a digital input of 00001. Find the value of V_{out} for an input 1111.

(c) Design a Mod-10 Asynchronous counter.

(d) Define EPROM. 2+3+4+1

(Syllabus : 2018-2019)

[Electromagnetic Theory]

Full Marks : 50

The figures in the margin indicate full marks.

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

Answer ***question no.*** **1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) Show that for electromagnetic wave propagating in free space, the electric field $\vec{E}$, the magnetic field $\vec{B}$ and the unit vector in the direction of propagation $\hat{n}$ are related by $c\vec{B} = \hat{n}\times\vec{E}$.

(b) The electric field component of a plane electromagnetic wave travelling in vacuum is given by $\vec{E}(z,t) = E_0\cos(kz-\omega t)\,\hat{x}$. Calculate the Poynting vector for this wave.

(c) A uniform volume charge density is placed inside a conductor with resistivity $10^{-3}\,\Omega$ m.

Find the time after which the charge density becomes $\frac{1}{e}$ of the original value.

[Given : $\epsilon_0 = 8{\cdot}854\times10^{-12}$ F/m]

(d) A certain material has a complex relative permittivity given by $\tilde{\epsilon}_r = 40 + 12i$ at 2·45 GHz. Estimate the depth over which the amplitude of the electric field inside the material falls to half of the external value.

(e) What should be the angle of the sun above the horizon so that sunlight reflected from a still lake is plane polarized? Given, refractive index of water = 1·33.

(f) Describe the state of polarization of the wave represented by

$$\vec{E}\left(z,t\right) = \hat{i}E_0\cos(kz-\omega t) - \hat{j}E_0\sin(kz-\omega t)$$

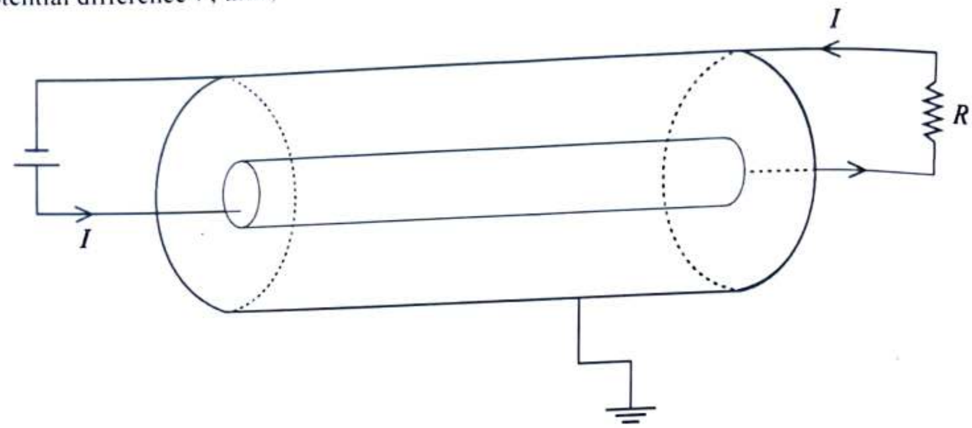
(g) Plane polarized light passes through a double refracting crystal of thickness 40 μm and emerges out as circularly polarized light. If the birefringence of the crystal is 4×10^{-5}, find the wavelength of the incident light.

2. (a) Write down wave equations for scalar potential $\phi\left(\vec{r},t\right)$ and vector potential $\vec{A}\left(\vec{r},t\right)$ in Coulomb gauge. Consider a charge and current-free region.

(b) Derive expressions for the electric and magnetic field in free space for the vector potential $\vec{A} = \hat{x}\,a\cos(kz-\omega t) + \hat{y}\,b\sin(kz-\omega t)$.

(c) A current flowing in a long solenoid with radius R is varied such that the magnetic field inside the solenoid has magnitude $B = \beta t^2$, where β is a constant. Calculate the electric field inside and outside the solenoid and hence find the displacement current density as a function of the distance r from the axis of the solenoid. 4+3+3

3. Consider a co-axial cable of negligible resistance. If this cable is inserted between a source of constant emf and some load R, a steady current I will flow down the cable. If the emf provides a constant potential difference V, then,



(a) What is the power supplied to the cable?

(b) If the inner and outer radii are 'a' and 'b' respectively, then write down the expressions of $\vec{E}$ and $\vec{B}$ in the region $(a < r < b)$. [Keep in mind the cylindrical geometry]

(c) Calculate $\vec{S}$, the Poynting vector.

(d) Calculate $\int \vec{S} \cdot d\vec{a}$ over the cross-sectional area of the cable between the inner and the outer conductors and find total electromagnetic power flow. 1+(2+2)+2+(2+1)

4. (a) An electromagnetic wave is incident on the plane interface between two different media.

(i) Show that the wave vectors of the incident, reflected and refracted waves all lie on the same plane.

(ii) Find the relation between the angles of incidence, reflection and refraction.

(b) The regions of space $z < 0$ and $z > 0$ are filled with materials having permeabilities $2\mu_0$ and $5\mu_0$ respectively. The magnetic field in the region $z > 0$ is $\vec{B}_2 = \mu_0\,(75\,\hat{x} + 40\,\hat{z})\,T$ and there is a surface current distribution $\vec{K} = -10\,\hat{y}\ A/m\ \ at\ z = 0$.

Find the possible magnetic field in the region $z < 0$.

(c) A plane electromagnetic wave is incident normally at the boundary of two dielectrics of refractive indices n_1 and n_2 $(n_1 < n_2)$. If the transmission co-efficient is required to be 0.80, what should be the value of $\frac{n_2}{n_1}$? (2+3)+3+2

5. (a) What is displacement current? Explain why and how Ampere's circuital law for steady current was modified to include displacement current.

(b) A plane electromagnetic wave travels in free space in the negative-z-direction with a propagation constant 20 rad/m, the amplitude of the magnetic field being $\frac{40}{377} A|m$. At $t = 0$, $z = 0$, the magnetic field is in the negative y-direction. Give the expression for electric field.

(c) If vector potential $\vec{A} = \beta x\hat{i} + 2y\,\hat{j} - 3z\hat{k}$ satisfies the Coulomb gauge condition, what is the value of β?

(d) Protons having the same velocity $\vec{v} = v\hat{z}$ form an infinite beam of circular cross-section with current I. Find the direction and magnitude of the Poynting vector $\vec{S}$ outside the beam at a distance r from its axis. (1+2)+2+2+3

6. (a) Discuss the state of polarization when the x and y components of the electric field are as follows:

(i) $E_x = E_0 \cos(kz + \omega t)$, $E_y = \frac{E_0}{\sqrt{2}} \cos(kz + \omega t + \pi)$

(ii) $E_x = E_0 \sin\left(kz - \omega t + \frac{\pi}{3}\right)$, $E_y = E_0 \sin\left(kz - \omega t - \frac{\pi}{6}\right)$

(b) What will be the Brewster angle for a glass slab ($n_g = 1{\cdot}5$) immersed in water ($n_w = 1{\cdot}33$)?

(c) Four perfect polarizing plates are stacked so that the axis of each is turned 30° clockwise with respect to the preceeding plate. How much of the intensity of an unpolarized incident beam of light is transmitted by the stack?

(d) For calcite the values of the refractive index for o-ray and e-ray are $n_0 = 1{\cdot}68134$ and $n_e = 1{\cdot}49694$ respectively, for light of wavelength $\lambda = 404{\cdot}6$ nm. However, corresponding to $\lambda = 706{\cdot}5$ nm their values are $n_0 = 1{\cdot}65267$ and $n_e = 1{\cdot}48359$ respectively. A calcite quarter wave plate is construction for $\lambda = 404{\cdot}6$ nm. If a left circularly polarized beam of $\lambda = 706{\cdot}5$ nm is incident on this plate, obtain the state of polarization of the emergent beam. 3+2+2+3

7. (a) Explain the phenomenon of double refraction in a uniaxial crystal on the basis of Huygen's theory.

(b) A 20 cm length of a certain optically active solution causes right-handed rotation of 40° and a 30 cm length of another solution, which does not chemically react with the first solution, causes left-handed rotation of 24°. What will be the optical rotation produced by 30 cm length of a mixture of the above solutions in volume ratio 1 : 2?

(c) Plane polarized light of wavelength 550 nm is incident on a quartz crystal parallel to the optic axis. Find the least thickness for which the o-ray and the e-rays combine to form plane polarized light. Given, their refractive indices are $\mu_o = 1{\cdot}5442$ and $\mu_e = 1{\cdot}5533$ respectively.

(d) Explain why if we hold a glass plate horizontally at the level of the eye (i.e., the angle of incidence is close to $\pi/2$) the plate acts like a mirror. 2+3+3+2
