## M. Sc. (Physics) 4<sup>th</sup> Semester Examination 2019

PHY - 523 Microwave (Elective)

## Full Marks – 50

Answer in your own words as far as practicable. The marks on the right-hand margin indicate the full marks for the question.

Answer Q. 1 and any three from the rest :-

Answer any ten of the following:-1.

- Write the full spelling of IMPATT. How frequency of an IMPATT oscillator is (i) related to the time of transit of the domains.
- Draw the I V characteristics of a Gunn diode acting as a microwave (ii) oscillator.
- Give expression for the time averaged power flow in an air filled rectangular (iii) wave guide.
- Draw the apple-gate diagram of a reflex Klystron. (iv)
- A c-w power of 100 mW is fed into port- 1 of a 20 dB directional coupler (v) having very high directivity. Calculate power output from port- 2, 3 and 4 respectively.
- Show that a quarter wave section can be used as an impedance inverter.
- Write down the separation equation for a circular cavity resonator and hence (vi) (vii) obtain the resonant frequency.
- The solution of Bessel's equation is  $R = C_n J_n + D_n N_n$ . Show why  $D_n = 0$  for (viii) wave propagation in a circular waveguide.
- Write an expression for the relative permeability of ferrite in a dc magnetic field and hence find the condition for "gyro-magnetic resonance". (ix)
- Define "coupling factor" and "directivity" of a microwave directional coupler.
- Write down the transportation characteristics of a microwave isolator. Explain (X)
- how these characteristics can be achieved with a circulator. (xi)Write down the S-matrix of a two-port waveguide-junction and hence explain
- the significances of each elements there-in. (xii)

Starting from Maxwell's Electromagnetic equations find expressions for the different electric and magnetic field components for TM modes in a circular wave guide. 10

3. (a) Draw the schematic diagram of a 2 cavity Klystron. Derive an expression for the velocity modulation in terms of other relevant parameters.

(b) What is IMPATT diode ? With neat sketch briefly explain how these diodes exhibit negative differential resistance.

## Time - 2 hours

 $2 \times 10 = 20$ 

4. (a) A coaxial cylindrical wave guide of internal radius 'b' and central conductor of 4. (a) A coaxial cylindrical wave guide of means by wave theory that the power that the power is impressed in the power is impressed. radius 'a' have air dielectric between them. Show a current of  $I_0 e^{-j\omega t}$  is impressed on transmitted through the wave guide is  $\frac{1}{2}V_0 I_0$  when a current of  $I_0 e^{-j\omega t}$  is impressed on the central conductor. 4 (b) What is Faraday's rotation ? Explain with a neat sketch the construction of a (b) What is Faraday's rotation f Explanate be used to construct a 4-port microwave gyrator. How a gyrator and two magic tees can be used to construct a 4-port microwave circulator. Write the s-matrix of an ideal circulator. 6 5. (a) Starting from Maxwell's Electromagnetic equations find the expression for cutoff frequency (in terms of wave guide dimensions) for a rectangular wave guide. 3

(b) Hence derive expressions for the phase constant, phase velocity, wave length and impedance in the guide.

(c) Show that any loss-less, non-reciprocal, ideal three port waveguide junction is a perfect circulator. 5

6. (a) What is matching in a transmission line. State the advantages of stub matching over lumped element matching ? 2

(b) The terminating impedance of a loss-less transmission line is  $Z_1 = 100 + j 100 \Omega$ , and the characteristic impedance of the line as well as the short circuited stub  $Z_0$  is 50  $\Omega$ . The 1<sup>st</sup> stub is placed at 0.40  $\lambda$  away from the load. The spacing between the two stubs is  $3/8 \lambda$ . Determine the length of the stubs when perfect matching is achieved. 8

(b)

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Ans

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4. (a) Establish the equation of motion for a free particle in a curved space-time. From the definition of the Christoffel symbol, show that

$$\Gamma^{\sigma}_{\lambda\mu} = \frac{1}{2} g^{\nu\sigma} \left\{ \frac{\partial g_{\mu\nu}}{\partial x^{\lambda}} + \frac{\partial g_{\lambda\nu}}{\partial x^{\mu}} - \frac{\partial g_{\mu\lambda}}{\partial x^{\nu}} \right\} ,$$

where  $g_{\mu\nu}$  is the metric for the curved space-time  $x^{\mu}$ .

(b) If the metric is given by

$$ds^{2} = -dt^{2} + a^{2}(t) \left[ \frac{dr^{2}}{1 - kr^{2}} + r^{2} d\theta^{2} + r^{2} \sin^{2} \theta d\phi^{2} \right] ,$$

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find  $\Gamma^r_{\phi\phi}$  and  $\Gamma^t_{rt}$ .

(c) The gravitational redshift, with c = 1, is given by the difference of the gravitational potentials at emitter and receiver points. Calculate the gravitational redshift if the emitter is on the surface of the sun and the receiver is in vacuum. Use the relevant values given at the end of the paper. (2+3) + 3 + 2

5. (a) Show that the first Friedmann equation

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho}{3}$$

and the fluid equation

$$\dot{\rho} + 3\frac{\dot{a}}{a}\left(\rho + p\right) = 0$$

lead to the second Friedmann equation

$$\frac{1}{a^2}\left(2a\ddot{a}+\dot{a}^2\right)=-8\pi Gp\,.$$

Take a flat universe with  $\Lambda = 0$ .

(b) If the equation of state of the cosmological fluid be  $p = (\gamma - 1)\rho$  where  $0 < \gamma < 2$  is some constant, find how the density and the Hubble parameter change with time. Show that  $\gamma = 0$  leads to an exponential expansion. Argue whether  $\dot{a} > c$  violate special relativity.

(c) Find the critical density of the universe at the present epoch if  $H_0 = 67 \text{ km/s/Mpc}$ .

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6. (a) Consider the relic abundance problem where the relic is the magnetic monopole. If  $\Omega_{mon}/\Omega_{rad} = 10^{-10}$  at  $T = 2 \times 10^{29}$  K, when did the matter-radiation transition took place? (Assume all matter in the form of such monopoles; the temperature was still so high that everything else was relativistic.) Since then, the universe was matter-dominated; what is the present value of  $\Omega_{mon}/\Omega_{rad}$ ? (b) Why does one need the baryon number violating interactions to proceed out of thermal equilibrium for baryogenesis?

(c) Draw the Hertzsprung-Russell diagram for main sequence stars, indicating the different stellar classes.

(d) Explain why the solar spectra show very weak hydrogen Balmer lines although the outer part of the sun is predominantly made of hydrogen.

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