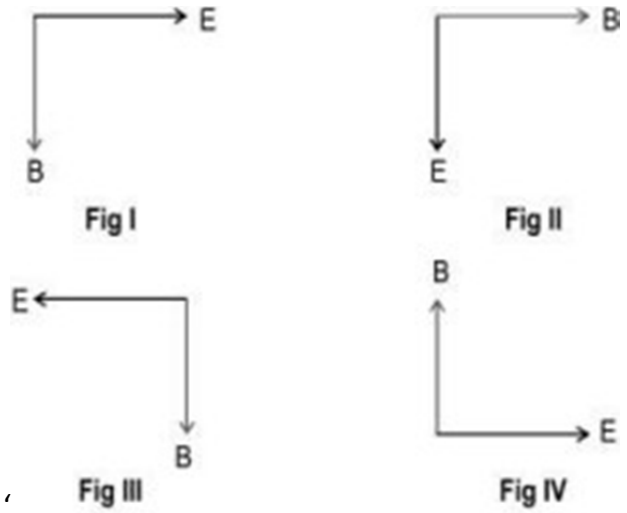
7. ELECTROMAGNETIC WAVES

Q. No	Question	Marks
	Multiple Choice Question	
Q.134	Study the following statements carefully. A. Electric and magnetic fields have zero average value in a plane em wave. B. For an em wave, the ratio k/ω is independent of wavelength. C. In an em wave, the E and B fields vary with the same frequency and are in opposite phase. D. Since E = cB, the energy associated with the electric field is much greater than that associated with the magnetic field. Identify the correct option. A. only A and B are correct B. only C and D are correct C. only A and C are correct D. only B and D are correct	1
Q.135	Which of the following statement/s are incorrect? A. The displacement current flows in a dielectric of the capacitor when the potential difference across its plates is decreasing with time. B. The direction of propagation of electromagnetic waves is given by $\vec{E} \times \vec{B}$ C. The dimensions of $\in_0 \frac{d\varphi_E}{dt}$ are the same as that of electric voltage. D. Instantaneous energy flow rate is a constant for an electromagnetic wave. E. Light of uniform intensity shines perpendicularly on a totally absorbing surface. On decreasing the area of the surface, the intensity remains the same. A. Only statements A & B B. Only statements C & D C. Only statements D & E D. Only statements A, C & D	1

Q.136	The diagrams below show the electric and magnetic field components of an electromagnetic wave at a certain time and location. Which of these electromagnetic waves are travelling towards you?  A. only the em wave in Fig I B. only the em wave in Fig I and II C. only the em wave in Fig II and III D. only the em wave in Fig II, III and IV	1
Free Response Question / Subjective Question		
Q.137	An electromagnetic wave of frequency 1 GHz travels through an empty space along the z-direction. At a specific point in space, the electric field E attains a maximum value of 50 V/m. If the electric wave is polarized along x-axis, then, (a) explain and identify the plane in which the magnetic field B will lie. (b) express the electric and magnetic fields as a function ofz and t.	3
Q.138	In a spaceship orbiting around the Earth, two astronauts stationed 2 m apart are speaking to each other. The conversation is transmitted to Earth via electromagnetic waves. Given that the sound waves travel through the air between the two astronauts in exactly the same time as the em waves take to reach the Earth ground station. Calculate the distance of the spaceship from the ground station. Take speed of sound in the air between the two astronauts as 340 m/s.	2

Q.139	An unfortunate nuclear explosion leaves behind the residual gamma radiations in the vicinity of the explosion site with an average energy density of 4 × 10−14 J/m3. (a) What is the rms value of the electric field of the radiation? (b) Compare the electric field strength with the magnetic field strength in this residual radiation.	2
Q.140	A dish antenna with a circular aperture of a radius 20 cm, receives digital TV signals from a satellite. The average intensity of the em waves that carry a particular TV program is 5×10^{-14} W/m2. Determine the following: (a) electromagnetic energy delivered to the dish during the telecast of 30 minutes of a programme. (b) average energy density of the em wave.	2
Q.141	A laser emits a sinusoidal em wave of wavelength 10 μm along the x-axis. The E field of the wave is parallel to the –ve z-axis with a maximum value of 1 MV/m. Express the wave equation for E and B for this wave with all appropriate values and directions.	3
Q.142	A satellite at a height of 100 km from the Earth's surface detects a radio signal emitted by a radio station on the ground. If the average power of the signal received is 100 kW, find the amplitudes E0 and B0 of the incoming signal.	3

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.134	A. only A and B are correct	1
Q.135	B. Only statements C & D	1
Q.136	D. only the em wave in Fig II, III and IV	1
Q.137	(a) Since E wave is polarized along x-direction and the em wave propagates along z-direction, the magnetic field vector has to be perpendicular to both E wave and the direction of propagation of the wave. So, B vector is aligned along y axis and lies in y-z plane. [1 mark for correct explanation and the direction] (b) The standard waveforms of E and B vector in an em wave are: $E = E_o \sin(kz - \omega t)$ $B = B_o \sin(kz - \omega t)$ $B_o = E_o/c = 50/c$ T $k = 2\pi/\lambda = 2\pi\, \nu/c = 2\pi \times 10^9/c$ $E = 50 \sin\left(\frac{2\pi \times 10^9 z}{C} - 2\pi \times 10^9 . t\right)$ $E = 50 \sin [2\pi \times 10^9 . (z/c - t)]$ $B = (50/c).\sin [2\pi \times 10^9 . (z/c - t)]$ [1 mark for each correct final equation of E and B]	3
Q.138	For the travel of sound waves between the two astronauts: 2 / 340 = t ….(1) For the travel of em waves from the spaceship to the Earth station: d/(3 x 108) = t ….(2) [0.5 mark for each of the equations for sound and em waves] Equating (1) and (2) and solving for d, d ≈ 1765 km [1 mark for correct final result]	2

Q.139	a. As energy density $u = \varepsilon_0 E_2$ $E_{rms} = \sqrt{\frac{u}{\varepsilon_0}} = \sqrt{\frac{4 \times 10^{-14}}{8.85 \times 10^{-12}}}$ = 0.067 N/C [1 mark for the correct finalresult] b. In any em radiation, the ratio E/B = c, is always constant [1 mark for the correct application of the ratio between E to B in any em wave]	2
Q.140	(a) Average intensity I = average power P /area A Average power P = I. A = I. πr^2 Average energy delivered during the telecast = I. πr^2. t [0.5 mark for correct formula of energy in terms of intensity, area and time] $E = 5 \times 10^{-14} \times \pi \times (0.2)^2 \times 1800$ $= 11.3 \times 10^{-12}$ J [0.5 mark for correct value of energy] (b) Energy density $u = I/c = 5 \times 10^{-14} / 3 \times 10^8 = 1.66 \times 10^{-22}$ J/m^3[1 mark for correct result of energy density]	2
Q.141	The standard wave equations: E-z = $E_o \sin(kx - \omega t)$ … direction of E field will be along –z-axis By = Bo sin(kx - ωt) .. direction of B field will be along y-axis Where $B_o = E_o/c = 10^6/3 \times 10^8 = 3.3 \times 10^{-3}$ T $k = 2\pi/\lambda = 2\pi / 10 \times 10^{-6} = 2\pi \times 10^5$ /m $\omega = ck = 3 \times 10^8 \times 2\pi \times 10^5 = 6\pi \times 10^{13}$ rad/s [0.5 mark for correct representation of E and correct values of B_o, k and ω] Equations: E-z = - k (10^6 V/m) sin($2\pi \times 10^5$. x - $6\pi \times 10^{13}$ .t) By = j (3.3×10^{-3} T) sin($2\pi \times 10^5$. x - $6\pi \times 10^{13}$ .t) [0.5 mark for each of E and B equations]	3
Q.142	Surface area of the hemisphere on the ground through which the signal is emitted by the radio station $A = 2\pi R^2 = 2\pi (100 \times 1000)2 = 2\pi \times 1010$ m [0.5 mark for correct calculation of surface area]	

	Intensity of the signal received by the satellite = I = Average power/ Area = 100 x 1000 / 2π x 1010 = 10-5/2π W/m_2 [1 mark for correct calculation of Intensity of signal] As $I = \epsilon_o E^2_{rms} c$ $E_{rms} = \sqrt{\frac{I}{\epsilon_0 c}}$ $E_0 = \sqrt{\frac{2I}{\epsilon_0 c}} = \sqrt{\frac{2 \times 10^{-5}}{2\pi \times 8.85 \times 10^{-12} \times 3 \times 10^8}}$ $E_o = 0.034$ V/m [1 mark for correct calculation of E_o] $B_o = E_o/c = 0.0115$ x 10-8 T [0.5 mark for correct calculation of B_o]	