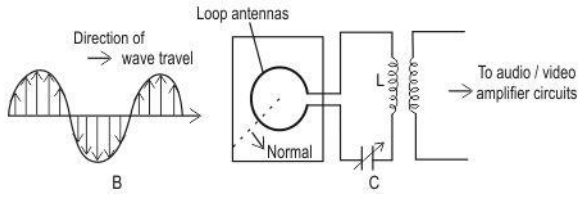
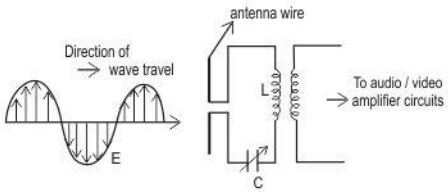
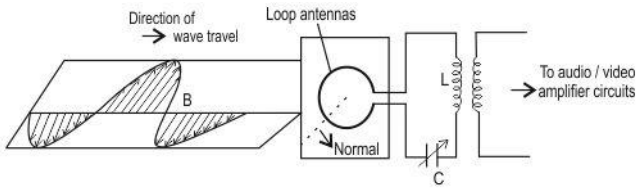
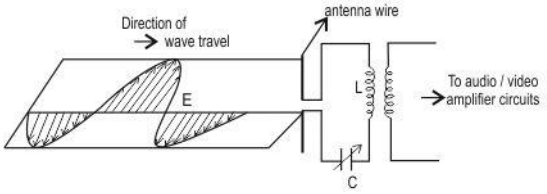
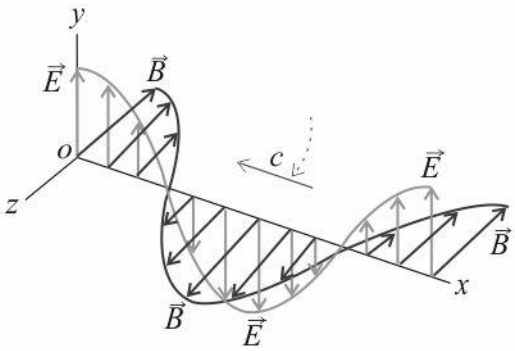
Electromagnetic Waves

Q.No	Question	Marks
	Multiple Choice Question	
Q.221	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): An oscillating electric charge loses energy. Reason(R): An oscillating electric charge radiates em waves. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	1
Q.222	Radio and television reception involves a process wherein broadcasted waves reach receiving antennae and interact with the electric charges in the antenna. Depending upon the shape, the antenna either interacts with the oscillating electric field vectors or magnetic field vectors of the em wave. In either case, the electrons experience force (electric or magnetic), and are set into alternating motion, thereby inducing the time varying current that is transmitted through the antennae as the signals. Study the figures carefully. In each of the following figures, either E or B waves are omitted in the receiving wave for simplicity. Study the following orientations of the antennae (wire & the loop). I.  II. 	1

	III.  IV.  Select the orientations that result in the best reception of the incoming signals by the antennae. A. Only I and IV B. Only II and III C. Only II and IV D. Only I and III	
Q.223	The diagram below shows a single EM wave of wavelength λ. For different values of x given as x = 0, λ/4, λ/2, 3λ/4 and λ, which of the following statements are correct.  I. Energy density is maximum at x = 0, λ/2 and λ II. Magnitude of instantaneous intensity is minimum at x = λ/4, 3λ/4 III. Energy density and the magnitude of instantaneous intensity have minimum values at positions where E and B are both zero. A. Only I is true B. Only II is true C. Only III is true D. All statements I, II & III are true	1
Free Response Questions/Subjective Questions		
Q.224	A 2 mW laser beam is pointed on a 1 mm^2 area. (a) What is the intensity of the beam in W/m^2?	4

	(b) If a 1 nC static charge is intercepted by this beam, what is the maximum electric force that the charge experiences? (c) What is the maximum magnetic force that acts on this charge if it is set into a motion at 500 m/s? (d) Justify that the electric force exerted by the em wave on the static charge is $\sim 10^6$ times the magnetic force on the moving charge as in the part (c).	
Q.225	(a) Given the direction of electric and magnetic fields, how is the direction of an em wave determined? (b) Suggest a pair of varying Electric (E_x or E_y or E_z) and magnetic field (B_x or B_y or B_z) vectors that would generate a plane electromagnetic wave travelling along –z direction.	2
Q.226	Consider a radiation whose magnetic field component is given by $B = 10^{-3}\cos(4 \times 10^{10}\pi x + 12\pi \times 10^{18}t)$ Wb m^{-2}. What will be the mass of a particle whose momentum is the same as that of the photon of this radiation and whose speed is 1000 times smaller than that of the photon? ($h = 6.626 \times 10^{-34}$ J s)	3

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.221	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.222	B. Only II and III	1
Q.223	D. All statements I, II & III are true	1
Q.224	(a) Intensity of the em beam I = Power/area = 2 x 10^{-3} / 10^{-6} = 2000 W/m^2 (1 mark for the correct value of the intensity]) (b) Intensity I of the em beam is also given as = ½ $c\in_o E_o^2$ (= ½ of electric field energy density x c) $E_0 = \sqrt{\frac{2I}{c\epsilon_0}} = \sqrt{\frac{2\times2000}{3\times10^8\times8.85\times10^{-12}}}$ E_0 = 1.22 x 10^3 N/C (0.5 mark for the correct value of E_0) Maximum force of the static charge, F = qE_o = 1 x 10^{-9} x 1.22 x 10^3 = 1.22 x 10^{-6} N (0.5 mark for the correct value of F) (c) Max. magnetic force of a moving charge, $F_B = qvB_o = qvE_o/c$ = 1 x 10^{-9} x 500 x 1.22 x 10^3 / 3 x 10^8 = 2 x 10^{-12} N (1 mark for the correct value of F_B) (d) Ratio F_E/F_B = 1.22 x 10^{-6} / 2 x 10^{-12} ~ 10^6 So the electric force exerted by the em wave on the static charge is ~ 10^6 times the magnetic force on the moving charge. (1 mark for the correct relation between F_E and F_B)	4
Q.225	(a) The direction of the em wave is given by the cross product of electric and magnetic vectors (E x B) (1 mark) (b) E_y and B_x would generate an em wave along –z direction. (1 mark)	2

Q.226	The momentum (p) of a photon is given by the equation: $p = E/c$ Where, E = energy of the photon c = speed of light The energy of a photon is related to its frequency (f) by the equation: $E = hf$ Where: E = energy, h = Planck's constant, f = frequency Thus, $p = hf/c$ The momentum of the particle is given by mv and as per the question we need $mv = hf/c$ $mc/1000 = hf/c$ $m = 1000hf/c^2$ Comparing the equation of B with $B = B_0 \cos(2\pi x/\lambda + 2\pi ft)$ We have, $f = 6 \times 10^{18}$ Hz $m = 1000 \times 6 \times 10^{18} \times h/(3 \times 10^8)^2$ $= 2/3 \times 10^5 \times 6.626 \times 10^{-34}$ $= 4.42 \times 10^{-29}$ kg [0.5 marks each for the formula of momentum of photon and that of energy of photon] [0.5 mark for finding frequency from the equation of B and 0.5 mark for writing an expression for the momentum of a particle] [1 mark for final answer]	3