CLASS – 12

WORKSHEET- ELECTROMAGNETIC WAVES

A. MAXWELLS- AMPERE'S LAW & DISPLACEMENT CURRENT

(1 Mark Questions)

1. How is displacement current produced between the plates of a parallel plate capacitor during charging?

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2. The charging current for a capacitor is 0.25A. What is the displacement current across the plates?

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3. A capacitor has been charged by a dc source. What are the magnitude of conduction and displacement current, when it is fully charged?

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(2 Marks Questions)

4. A parallel plate capacitor of plate area A each and separation d, is being charged by an ac source. Show that the displacement current inside the capacitor is the same as the current charging the capacitor.

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5. How does Ampere-Maxwell law explain the flow of current through a capacitor when it is being charged by a battery? Write the expression for the displacement current in terms of the rate of change of electric flux.

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6. Why does current in a steady state not flow in a capacitor connected across a battery? However momentary current does flow during charging or discharging of the capacitor. Explain.

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7. A capacitor, made of two parallel plates each of plate area A and separation d, is being charged by an external ac source. Show that the displacement current inside the capacitor is the same as the current charging the capacitor.

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8. When an ideal capacitor is charged by a dc battery, no current flows. However, when an ac source is used, the current flows continuously. How does one explain this, based on the concept of displacement current?

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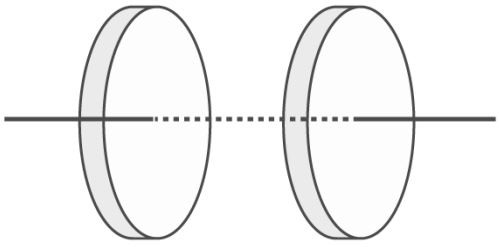
(3 Marks Questions)

9. The Figure shows a capacitor made of two circular plates each of radius 12 cm and separated by 5.0 cm. The capacitor is being charged by an external source (not shown in the figure). The charging current is constant and equal to 0.15A.
(a) Calculate the capacitance and the rate of change of the potential difference between the plates.
(b) Obtain the displacement current across the plates.
(c) Is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain.



[Ans.(a) 80.1pF, $1.875\times10^{9}Vs^{-1}$ (b) 0.15A (c) Yes]

10. Write Maxwell's generalization of Ampere's Circuital Law. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is: $i = \varepsilon_0 \frac{d\phi_\varepsilon}{dt}$ ϕ_ε where is the electric flux produced during charging of the capacitor plates.

B. ELECTROMAGNETIC WAVE

(1 Mark Questions)

1. Answer the following questions: (1 mark each)

(a) Long distance radio broadcasts use short-wave bands. Why?

(b) It is necessary to use satellite for long distance TV transmission. Why?

(c) Optical and radio-telescopes are built on the ground by X-ray astronomy is possible only from satellites orbiting the earth. Why?

(d) The small ozone layer on top of the stratosphere is crucial for human survival. Why?

(e) If the earth did not have an atmosphere, would its average surface temperature by higher or lower than what it is now?

(f) Some scientists have predicted that a global nuclear war on the earth would be followed by a severe 'nuclear winter' with a devastating effect on life on earth. What might be the basis of this prediction?

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2. Depict the field diagram of an electromagnetic wave propagating strong positive X-axis with its electric field along Y-axis.

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3. Illustrate by giving suitable examples, how you can show that electromagnetic waves carry both energy and momentum.

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4. How is the speed of em-waves in vacuum determined by the electric and magnetic fields?

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5. Do electromagnetic waves carry energy and momentum?

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6. Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields.

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7. In which direction do the electric magnetic and magnetic field vectors oscillate in an electromagnetic wave propagating along the x-axis?

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8. What is the frequency of electromagnetic waves produced by oscillating charge of frequency υ?

9. A plane electromagnetic wave travels in vacuum along z-direction. What can you say about the direction of electric and magnetic field vectors?

10. A welder wears special glasses to protect his eyes mostly from the harmful effect of
(a) very intense visible light (b) infrared radiation
(c) ultraviolet rays (d) microwaves

11. Electromagnetic waves used as a diagnostic tool in medicine are
(a) X rays (b) ultraviolet rays (c) infrared radiations (d) ultrasonic waves

12. The small ozone layer on top of the stratosphere is crucial for human survival. Why?

13. Name the electromagnetic radiations used for the (a) water purification, and (b) eye surgery.

14. Why are microwaves considered suitable for radar systems used in aircraft navigation?

15. To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19}Hz belong?

16. Arrange the following electromagnetic waves in order of increasing frequency: γ-rays, Microwaves, infrared rays and Ultraviolet rays.

17. Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations and write the range of their frequency.

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18. Name the electromagnetic waves, which (i) maintain the Earth's warmth and (ii) are used in aircraft navigation.

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19. Name the physical quantity which remains same for microwaves of wavelength 1mm and UV radiations of 1600Å in vacuum.

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20. How are radio waves produced?

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21. Write two uses of microwaves.

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(2 Marks Questions)

22. What physical quantity is the same for X-rays of wavelength 10^{-10}m, the red light of wavelength 6800 Å and radiowaves of wavelength 500m?

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23. A plane electromagnetic wave travels in vacuum along the z-direction. What can you say about the directions of its electric and magnetic field vectors? If the frequency of the wave is 30 MHz, what is its wavelength? [Ans. 10m]

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24. A radio can tune in to any station in the 7.5 MHz to 12 MHz bands. What is the corresponding wavelength band? [Ans. 40 m to 25m]

25. A charged particle oscillates about its mean equilibrium position with a frequency of 10^9 Hz. What is the frequency of the electromagnetic waves produced by the oscillator? [Ans. 10^9 Hz]

26. The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is B_0=510 nT. What is the amplitude of the electric field part of the wave? [Ans. 153 N/C]

27. Which of the following electromagnetic waves has (a) minimum wavelength, and (b) minimum frequency? Write one use of each of these two waves: infrared waves, Microwaves, γ-rays and X-rays.

28. Gamma rays and radio waves travel with the same velocity in free space. Distinguish between them in terms of their origin and the main application.

29. Why are infrared waves often called heat waves? Explain.

30. Identify the electromagnetic waves whose wavelengths vary as (a) $10^{-12}m < \lambda < 10^{-8}m$ (b) $10^{-3}m < \lambda < 10^{-1}m$. Write one use for each.

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31. Identify the electromagnetic waves whose wavelength vary as (a) $10^{-11}m < \lambda < 10^{-14}m$ (b) $10^{-4}m < \lambda < 10^{-6}m$. Write one use for each.

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32. Name the types of em radiations which (i) are used in destroying cancer cells, (ii) cause tanning of the skin and (iii) maintain the earth's warmth. Write briefly a method of producing any one of these waves.

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33. (a) Arrange the following electromagnetic waves in the descending order of their wavelengths: (i) Microwaves (ii) Infra-red rays (iii) Ultra-violet radiation (iv) Gamma rays
(b) Write one use each of any two of them.

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34. Name the constituent radiation of electromagnetic spectrum which is used for
(i) aircraft navigation (ii) studying crystal structure. Write the frequency range for each.

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35. What does an electromagnetic wave consist of? On what factors does its velocity in a vacuum depend?

36. What oscillates in electromagnetic waves? Are these waves transverse or longitudinal?

37. What is the role of ozone in the atmosphere?

(3 Marks Questions)

38. The terminology of different parts of the electromagnetic spectrum is given in the text. Use the formula E = hν (for the energy of a quantum of radiation: photon) and obtain the photon energy in units of eV for different parts of the electromagnetic spectrum. In what way are the different scales of photon energies that you obtain related to the sources of electromagnetic radiation?

39. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 V m^{-1}.
(a) What is the wavelength of the wave?
(b) What is the amplitude of the oscillating magnetic field?
(c) Show that the average energy density of the $\vec{E}$ field equals the average energy density of the $\vec{B}$ field

40. About 5% of the power of a 100W light bulb is converted to visible radiation. What is the average intensity of visible radiation: (a) at a distance of 1m from the bulb (b) at a distance of 10m? [Ans. 0.4 Wm^{-2}, 0.004 Wm^{-2}]

41. Write the expression for the generalized form of Ampere's circuital law. Discuss its significance and describe briefly how the concept of displacement current is explained through charging/discharging of a capacitor in an electric circuit.

42. Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.

43. How are e.m. waves produced by oscillating charges? Draw a sketch of linear polarized e.m. waves propagating in the z-direction. Indicate the directions of the oscillating electric and magnetic fields.

44. Answer the following questions:
(i) Show by giving a simple example, how e.m. waves carry energy and momentum.
(ii) How are microwaves produced? Why is it necessary in microwave ovens to select the frequency of microwaves to match the resonant frequency of water molecules?
(iii) Write two important used of infrared waves.

45. State clearly how a microwave oven works to heat up a food item containing water molecules. Why are microwaves found useful for the radar systems in aircraft navigation?

46. Give one use of each of the following: (i) Microwaves (ii) Ultraviolet rays (iii) Infra-red rays (iv) Gamma rays.

47. The velocity of propagation (in vacuum) and the frequency of (i) X-rays and (ii) radio-waves are denoted by (v_x, n_x) and (v_R, n_R) respectively. How do the values of (a) v_x and v_R (b) n_x and n_R, compare with each other?

48. An e.m. wave is travelling in a medium with a velocity $\vec{v} = v\hat{i}$. The electric field oscillations, of this e.m. wave, are along the y-axis. (a) Identify the direction in which the magnetic field oscillations are taking place, of the e.m. wave. (b) How are the magnitudes of the electric field and magnetic fields in the electromagnetic wave related to each other?

49. The oscillating magnetic field in a plane electromagnetic wave is given by:

$$B_y = (8\times10^{-6}) \sin[2\times10^{11}t + 300\ \pi x]T$$

(i) Calculate the wavelength of the electromagnetic wave (ii) Write down the expression for the oscillating electric field.

50. The oscillating electric field of an electromagnetic wave is given by:

$$E_y = 30 \sin[2\times10^{11}\ t + \pi x]\ Vm^{-1}$$

(i) Obtain the value of wavelength of the electromagnetic wave (ii) Write down the expression for the oscillating magnetic field.

(5 Marks Questions)

51. Suppose that the electric field amplitude of an electromagnetic wave is $\vec{E}_0$**=120N/C^{-1}** and that its frequency is v = 50 MHz.(a) Determine $\vec{B}_0$**; ω, k and λ** (b) Find expressions for $\vec{E}$ and $\vec{B}$.
[Ans. (a) 4×10^{7}T, 3.14×10^{8} rads^{-1}, 1.05m^{-1}, 6.00m (b) $4\times10^{-7}\sin(1.05\chi - 3.14\times10^{8}t)\,\hat{j}$ tesla]

52. Suppose that the electric field of an electromagnetic wave in vacuum is (1 mark each)
$\vec{E} = 3.1(N/C)\cos[(18 rad/m)y + (5.4\times10^{8} rad/s)t]\hat{i}$
(a) What is the direction of the propagation?
(b) What is the wavelength λ?
(c) What is the frequency ν?
(d) What is the amplitude of the magnetic field part of the wave?
(e) What is the expression for the magnetic field part of the wave?
[Ans. (b) 3.5m (c) 86 MHz (d) 10.3 nT]

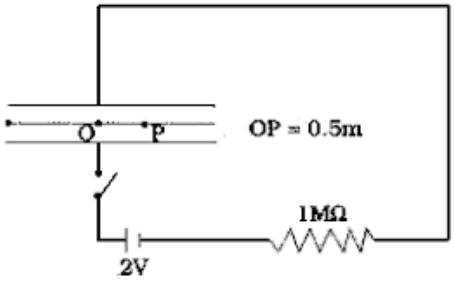
53. Given below are some famous numbers associated with electronic radiation in different contexts in physics. State the part of the e.m. spectrum to which each belongs:
(a) 21cm (wavelength emitted by atomic hydrogen in interstellar space).

(b) 1057 MHz (frequency of radiation arising from two close energy levels in hydrogen; known as Lamb shift)
(c) 27K (temperature associated with the isotropic radiation filling all space thought to be a relic of the 'big-bang' origin of universe)
(d) 5890C – 5896 C (doublet lines of sodium)
(e) 14.4 keV(energy of a particular transition) in Fe^{57} nucleus associated with a famous high resolution spectroscopic method (Mossbauer spectroscopy)

C. CHALLENGING PROBLEMS

1. A parallel plate capacitor made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with an (angular) frequency of 300 rad s^{-1}.
(a) What is the rms value of the conduction current?
(b) Is the conduction current equal to the displacement current?
(c) Determine the amplitude of B at a point 3.0 cm from the axis between the plates.
[Ans. 6.9 μA, 1.63×10^{-11}T,]

2. A parallel plate capacitor with circular plates of radius 1 m has a capacitance of 1 nF. At t = 0, it is connected for charging in series with a resistor R = 1 MΩ across a 2V battery (Fig. 8.3). Calculate the magnetic field at a point P, halfway between the centre and the periphery of the plates, after t = 10–3 s. (The charge on the capacitor at time t is q (t) = CV [1 – exp (–t/τ)], where the time constant τ is equal to CR.)



SPACE FOR ROUGH WORK

SPACE FOR NOTES