Series : X4YZW

SET ~ 3

रोल नं.
Roll No.

प्रश्न-पत्र कोड
Q.P. Code **55/4/3**

परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें।
Candidates must write the Q.P. Code on the title page of the answer-book.

भौतिक विज्ञान (सैद्धान्तिक)
PHYSICS (Theory)

निर्धारित समय : 3 घण्टे *अधिकतम अंक : 70*

Time allowed : 3 hours *Maximum Marks : 70*

नोट / NOTE #

(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ **31** हैं।
Please check that this question paper contains **31** printed pages.

(II) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें।
Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.

(III) कृपया जाँच कर लें कि इस प्रश्न-पत्र में **33** प्रश्न हैं।
Please check that this question paper contains **33** questions.

(IV) **कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में यथा स्थान पर प्रश्न का क्रमांक अवश्य लिखें।**
Please write down the Serial Number of the question in the answer-book at the given place before attempting it.

(V) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है। प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा। 10.15 बजे से 10.30 बजे तक परीक्षार्थी केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे।
15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the candidates will read the question paper only and will not write any answer on the answer-book during this period.

#

General Instructions :

Read the following instructions carefully and follow them :

(i) *This question paper contains **33** questions. **All** questions are **compulsory**.*

(ii) *This question paper is divided into **five** sections – **Sections A, B, C, D** and **E**.*

(iii) *In **Section A** – Questions no. **1** to **16** are Multiple Choice type questions. Each question carries **1** mark.*

(iv) *In **Section B** – Questions no. **17** to **21** are Very Short Answer type questions. Each question carries **2** marks.*

(v) *In **Section C** – Questions no. **22** to **28** are Short Answer type questions. Each question carries **3** marks.*

(vi) *In **Section D** – Questions no. **29** and **30** are case study-based questions. Each question carries **4** marks.*

(vii) *In **Section E** – Questions no. **31** to **33** are Long Answer type questions. Each question carries **5** marks.*

(viii) *There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section A.*

(ix) *Kindly note that there is a separate question paper for Visually Impaired candidates.*

(x) *Use of calculators is **not** allowed.*

You may use the following values of physical constants wherever necessary :

$c = 3 \times 10^8$ m/s

$h = 6{\cdot}63 \times 10^{-34}$ Js

$e = 1{\cdot}6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8{\cdot}854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}

Mass of electron (m_e) = $9{\cdot}1 \times 10^{-31}$ kg

Mass of neutron = $1{\cdot}675 \times 10^{-27}$ kg

Mass of proton = $1{\cdot}673 \times 10^{-27}$ kg

Avogadro's number = $6{\cdot}023 \times 10^{23}$ per gram mole

Boltzmann constant = $1{\cdot}38 \times 10^{-23}$ JK^{-1}

#

SECTION A

1. Two point charges Q and – q are held 'r' distance apart in free space. A uniform electric field $\vec{E}$ is applied in the region perpendicular to the line joining the two charges. Which one of the following angles will the direction of the net force acting on charge – q make with the line joining Q and – q ?

(A) $\tan^{-1} \frac{4\pi\varepsilon_0 E r^2}{Q}$ (B) $\cot^{-1} \frac{4\pi\varepsilon_0 E r^2}{Q}$

(C) $\tan^{-1} \frac{QE}{4\pi\varepsilon_0 r^2}$ (D) $\cot^{-1} \frac{QE}{4\pi\varepsilon_0 r^2}$

2. Three wires A, B and C of the same material have lengths and area of cross-sections as $(2l, \frac{A}{2})$, (l, A) and $(\frac{l}{2}, 2A)$, respectively. If the resistances of these wires are R_A, R_B and R_C respectively, then :

(A) $R_A > R_B > R_C$ (B) $R_B > R_C > R_A$

(C) $R_C > R_A > R_B$ (D) $R_A > R_C > R_B$

3. A particle of mass m and charge q moves along y-axis in a region in which a uniform magnetic field $\vec{B}$ is pointing along x-axis. The Lorentz force acting on the charge will point along :

(A) x-axis (B) y-axis

(C) z-axis (D) negative z-axis

4. A bar magnet is initially at right angles to a uniform magnetic field. The magnet is rotated till the torque acting on it becomes one-half of its initial value. The angle through which the bar magnet is rotated is :

(A) 30° (B) 45°

(C) 60° (D) 75°

5. Which of the following substances has magnetic permeability less than that of free space ?

(A) Sodium (B) Iron

(C) Aluminium (D) Copper

#

6. The magnetic flux linked with a closed coil (in Wb) varies with time t (in s) as $\phi = 5t^2 + 4t - 2$. If the resistance of the circuit is 14 Ω, the magnitude of induced current in the coil at t = 1 s will be :

(A) 0·5 A (B) 1·0 A

(C) 1·5 A (D) 2·0 A

7. In an electromagnetic wave travelling in free space, the amplitude of magnetic field is $6{\cdot}0 \times 10^{-4}$ T. The amplitude of its electric field is :

(A) 2×10^4 Vm^{-1} (B) $1{\cdot}5 \times 10^{12}$ Vm^{-1}

(C) $1{\cdot}8 \times 10^5$ Vm^{-1} (D) $0{\cdot}3 \times 10^4$ Vm^{-1}

8. A long straight wire is held vertically and carries a steady current in upward direction. The shape of magnetic field lines produced by the current-carrying wire are :

(A) horizontal straight lines directed radially out from the wire.

(B) straight lines parallel to the current-carrying wire.

(C) concentric horizonal circles around the wire.

(D) coaxial helixes around the wire.

9. The magnification produced by a spherical mirror is – 2·0. The mirror used and the nature of the image formed will be

(A) Convex and virtual

(B) Concave and real

(C) Concave and virtual

(D) Convex and real

10. Choose the correct statement :

(A) Photons of light show diffraction whereas electrons do not show diffraction.

(B) Electrons have momentum whereas photons do not have momentum.

(C) Photons of light and electrons both exhibit dual nature.

(D) All electromagnetic radiations do not have photons.

#

11. A beam of red light and a beam of blue light have equal intensities. Which of the following statements is true ?

(A) The blue beam has more number of photons than the red beam.

(B) The red beam has more number of photons than the blue beam.

(C) Wavelength of red light is lesser than wavelength of blue light.

(D) The blue light beam has lesser energy per photon than that in the red light beam.

12. Which of the following is an electrical conductor at room temperature ?

(A) Sn

(B) Mica

(C) Si

(D) C

*Questions number **13** to **16** are Assertion (A) and Reason (R) type questions. Two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below.*

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is ***not*** the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Both Assertion (A) and Reason (R) are false.

13. *Assertion (A) :* In double slit experiment if one slit is closed, diffraction pattern due to the other slit will appear on the screen.

Reason (R) : For interference, at least two waves are required.

#

14. *Assertion (A) :* For monochromatic incident radiation, the emitted photoelectrons from a given metal have speed ranging from zero to a certain maximum value.

Reason (R) : Each metal has a definite work function.

15. *Assertion (A) :* n-type semiconductor is not negatively charged.

Reason (R) : Neutral pentavalent impurity atom doped in intrinsic semiconductor (neutral) donates its fifth unpaired electron to the crystal lattice and becomes a positive donor.

16. *Assertion (A) :* A series LCR circuit behaves as a pure resistive circuit at resonance.

Reason (R) : At resonance, $X_L = X_C$ gives $\omega = \frac{1}{\sqrt{LC}}$.

SECTION B

17. In an intrinsic semiconductor, carrier's concentration is 5×10^8 m^{-3}. On doping with impurity atoms, the hole concentration becomes 8×10^{12} m^{-3}.

(a) Identify (i) the type of dopant and (ii) the extrinsic semiconductor so formed.

(b) Calculate the electron concentration in the extrinsic semiconductor. *2*

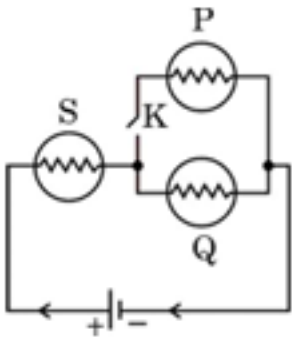
18. In Young's double slit experiment, the screen is moved 30 cm towards the slits. As a consequence, the fringe width of the pattern changes by 0·09 mm. If the slits separation used is 2 mm, calculate the wavelength of light used in the experiment. *2*

19. The two surfaces of a biconvex lens are of radius of curvature 'R' each. Obtain the condition under which its focal length 'f' be equal to 'R'. If one of the two surfaces of this lens is made plane, what will be the new focal length of the lens ? *2*

#

20. In Bohr's model of hydrogen atom, find the percentage change in the radius of its orbit when an electron makes a transition from n = 3 state to n = 2 state. *2*

21. (a) In the given figure, three identical bulbs P, Q and S are connected to a battery.



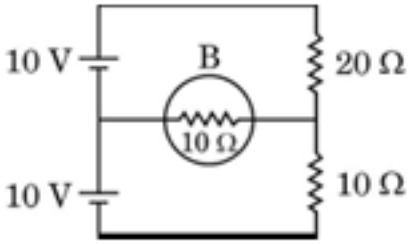
(i) Compare the brightness of bulbs P and Q with that of bulb S when key K is closed.

(ii) Compare the brightness of the bulbs S and Q when the key K is opened.

Justify your answer in both cases. *2*

OR

(b) Two cells of emf 10 V each, two resistors of 20 Ω and 10 Ω and a bulb B of 10 Ω resistance are connected together as shown in the figure. Find the current that flows through the bulb. *2*



SECTION C

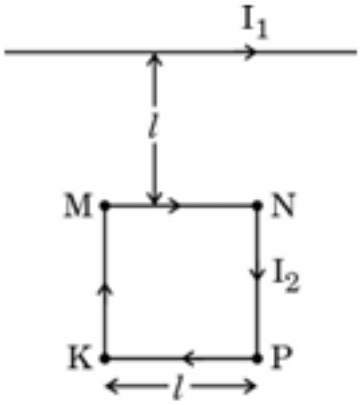
22. (a) What are majority and minority charge carriers of p-type and n-type semiconductors ?

(b) Explain briefly the formation of diffusion current and drift current in a p-n junction diode. *3*

#

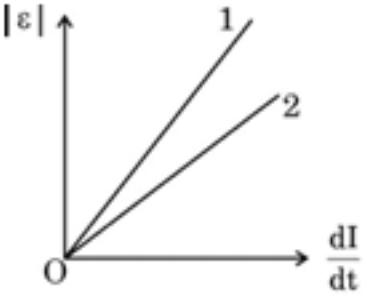
23. (a) In which cases does a charged particle not experience a force in a magnetic field ?

(b) A square loop **MNPK** of side 'l' carrying a current 'I_2' is kept close to a long straight wire in the same plane and the wire carries a steady current I_1 as shown in the figure. Obtain the magnitude of magnetic force exerted by the wire on the loop. *3*



24. (a) Obtain an expression for the self-inductance of a long solenoid of length 'l', cross-sectional area 'A' and having 'N' turns.

(b) The figure shows the plot of magnitude of induced emf (ε) versus the rate of change of current in two coils '1' and '2'. Which coil has greater value of self-inductance and why ? *3*



25. Explain the following observations using Einstein's photoelectric equation : *3*

(a) Photoelectric emission does not occur from a surface when the frequency of the light incident on it is less than a certain minimum value.

(b) It is the frequency, and not the intensity of the incident light which affects the maximum kinetic energy of the photoelectrons.

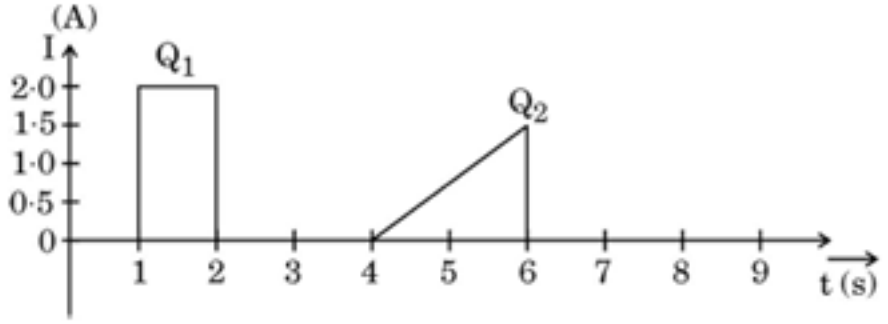
(c) The cut-off voltage (V_o) versus frequency (ν) of the incident light curve is a straight line with a slope $\frac{h}{e}$.

26. (a) Write the conditions under which two light waves originating from two coherent sources can interfere each other (i) constructively, and (ii) destructively, in terms of wavelength. Can these be applied for two lights originating from two sodium lamps ? Give reason.

(b) **Monochromatic light of green colour is used in Young's double slit** experiment and an interference pattern is observed on a screen. If the green light is replaced by red monochromatic light of the same intensity, how will the fringe width of interference pattern be affected ? Justify your answer. *3*

27. (a) (i) Derive an expression for the resistivity of a conductor in terms of number density of free electrons and relaxation time.

(ii) The figure shows the plot of current through a cross-section of wire over two different time intervals. Compare the charges (Q_1 and Q_2) that pass through the cross-section during these time intervals. *3*



OR

(b) (i) A battery of emf E and internal resistance r is connected to a variable external resistance R.

(I) Obtain the expression for current I in the circuit and the value of maximum current the battery can supply.

(II) Obtain the terminal voltage V across the battery and its maximum possible value.

#

(ii) The above battery sends a current I_1 when $R = R_1$ and a current I_2 when $R = R_2$. Obtain the internal resistance of the battery in terms of I_1, I_2, R_1 and R_2. *3*

28. (a) State any three characteristics of electromagnetic waves.

(b) Briefly explain how and where the displacement current exists during the charging of a capacitor. *3*

SECTION D

*Questions number **29** and **30** are Case Study-based questions. Read the following paragraphs and answer the questions that follow.*

29. A hydrogen atom consists of an electron revolving in a circular orbit of radius r with certain velocity v around a proton located at the nucleus of the atom. The electrostatic force of attraction between the revolving electron and the proton provides the requisite centripetal force to keep it in the orbit. According to Bohr's model, an electron can revolve only in certain stable orbits. The angular momentum of the electron in these orbits is some integral multiple of $\frac{h}{2\pi}$, where h is the Planck's constant.

Further, when an electron makes a transition from one orbit of higher energy to that of lower energy, a photon is emitted having energy equal to the difference between energies of the initial and final states. Assuming the mass and charge of an electron as m and e respectively, answer the following questions.

(i) The expression for the speed of electron v in terms of radius of the orbit (r) and physical constant ($K = \frac{1}{4\pi\varepsilon_0}$) is : *1*

(A) $\frac{Ke^2}{mr}$ (B) $\frac{Ke^2}{mr^2}$

(C) $\sqrt{\frac{Ke^2}{mr}}$ (D) $\sqrt{\frac{Ke^2}{mr^2}}$

#

(ii) The total energy of the atom in terms of r and physical constant K is : 1

(A) $\frac{Ke^2}{r}$ (B) $-\frac{Ke^2}{2r}$

(C) $\frac{Ke^2}{2r}$ (D) $\frac{3}{2}\frac{Ke^2}{r}$

(iii) A photon of wavelength 500 nm is emitted when an electron makes a transition from one state to the other state in an atom. The change in the total energy of the electron and change in its kinetic energy in eV as per Bohr's model, respectively will be : 1

(A) 2·48, – 2·48 (B) – 1·24, 1·24

(C) – 2·48, 2·48 (D) 1·24, – 1·24

(iv) (a) In Bohr's model of hydrogen atom, the frequency of revolution of electron in its n^{th} orbit is proportional to : 1

(A) n

(B) $\frac{1}{n}$

(C) $\frac{1}{n^2}$

(D) $\frac{1}{n^3}$

OR

(b) An electron makes a transition from – 3·4 eV state to the ground state in hydrogen atom. Its radius of orbit changes by : (radius of orbit of electron in ground state = 0·53 Å) 1

(A) 0·53 Å

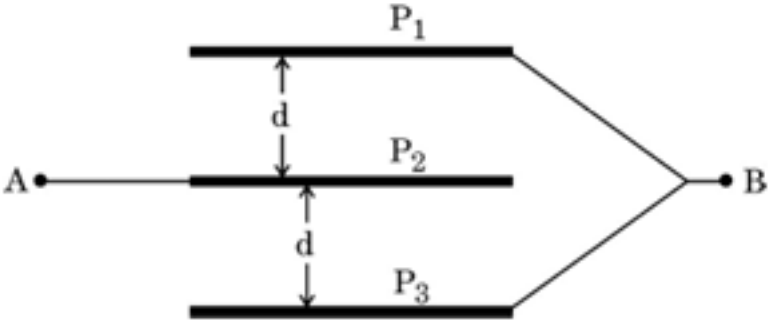
(B) 1·06 Å

(C) 1·59 Å

(D) 2·12 Å

#

30. A parallel plate capacitor consists of two conducting plates kept generally parallel to each other at a distance. When the capacitor is charged, the charge resides on the inner surfaces of the plates and an electric field is set up between them. Thus, electrostatic energy is stored in the capacitor. The figure shows three large square metallic plates, each of side 'L' held parallel and equidistant from each other. The space between P_1 and P_2 and P_2 and P_3 is completely filled with mica sheets of dielectric constant 'K'. The plate P_2 is connected to point A and other plates P_1 and P_3 are connected to point B. Point A is maintained at a positive potential with respect to point B and the potential difference between A and B is V.



(i) The capacitance of the system between A and B will be : *1*

(A) $\frac{\varepsilon_0 KL^2}{d}$ (B) $\frac{\varepsilon_0 KL^2}{2d}$

(C) $\frac{2\varepsilon_0 KL^2}{d}$ (D) $\frac{2\varepsilon_0 Kd}{L^2}$

(ii) The charge on plate P_1 is : *1*

(A) $\frac{\varepsilon_0 VKL^2}{2d}$ (B) $\frac{\varepsilon_0 VKL^2}{d}$

(C) $\frac{2\varepsilon_0 VKL^2}{d}$ (D) $\frac{\varepsilon_0 VKL^2}{4d}$

(iii) The electric field in the region between P_1 and P_2 is : *1*

(A) $\frac{V}{d}$ (B) $\frac{2V}{d}$

(C) $\frac{V}{2d}$ (D) $\frac{d}{V}$

#

(iv) (a) The separation between the plates of same area (L^2) of a parallel plate air capacitor having capacitance equal to that of this system, will be : *1*

(A) $\frac{d}{K}$ (B) $\frac{2d}{K}$

(C) $\frac{d}{2K}$ (D) $\frac{d}{4K}$

OR

(b) If the source of potential difference applied between A and B is removed, and then A and B are connected by a conducting wire, the net charge on the system will be : *1*

(A) $\frac{\varepsilon_0 \, VKL^2}{4d}$ (B) $\frac{\varepsilon_0 \, VKL^2}{2d}$

(C) $\frac{\varepsilon_0 \, VKL^2}{d}$ (D) Zero

SECTION E

31. (a) (i) An object is placed 30 cm from a thin convex lens of focal length 10 cm. The lens forms a sharp image on a screen. If a thin concave lens is placed in contact with the convex lens, the sharp image on the screen is formed when the screen is moved by 45 cm from its initial position. Calculate the focal length of the concave lens.

(ii) Calculate the angle of minimum deviation of an equilateral prism. The refractive index of the prism is $\sqrt{3}$. Calculate the angle of incidence for this case of minimum deviation also. *5*

OR

#

(b) (i) A physics teacher wants to demonstrate interference with the help of double slit experiment using a laser beam of 633 nm wavelength. Since the hall is large enough, interference pattern is formed on the wall 5·0 m from the slits. For clear and comfortable view by all the students they want the fringe width 5 mm.

(I) Find the slit separation for obtaining the desired interference pattern.

(II) How far will the first minimum be from the central maximum ?

(ii) A parallel beam of light of wavelength 650 nm passes through a slit of width 0·6 mm. The diffraction pattern is obtained on a screen kept 60 cm away from the slit. Find the distance between first order minima on both sides of the central maximum. *5*

32. (a) (i) Two point charges + q and – q are held at (a, 0) and (– a, 0) in x-y plane. Obtain an expression for the net electric field due to the charges at a point (0, y). Hence, find electric field at a far off point (y >> a).

(ii) Three point charges of – 2 nC, – 1 nC, and + 5 nC are kept at the vertices A, B and C of an equilateral triangle of side 0·2 m. Find the total amount of work done in shifting the charges from A to A_1, B to B_1 and C to C_1. Here A_1, B_1 and C_1 are the midpoints of sides AB, BC and CA, respectively. *5*

OR

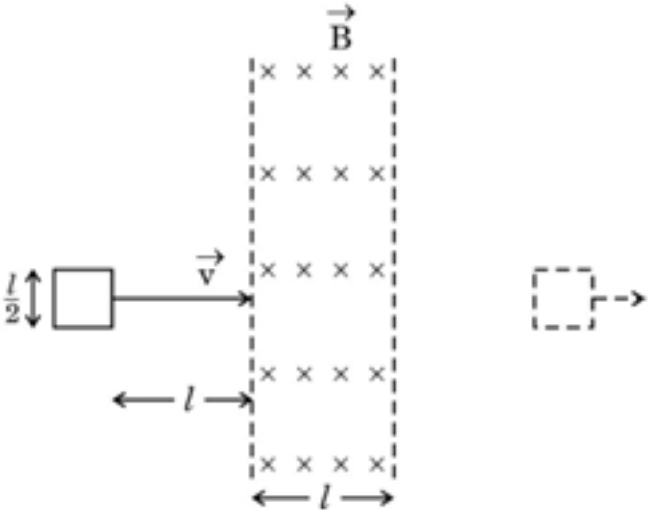
(b) (i) Show that Gauss's theorem is consistent with Coulomb's law. Using it, derive an expression for the electric field due to a uniformly charged thin spherical shell of radius r at a point at a distance y from the centre of the shell such that (I) y > r, and (II) y < r.

#

(ii) A point charge of + 2 nC is kept at the origin of a three-dimensional coordinate system. Find the type and magnitude of the charge which should be kept at (0, 0, – 6m) so that the potential due to the system becomes zero at (0, 0, 2m). *5*

33. (a) (i) **State Lenz's law and explain how this law is a consequence of conservation of energy principle.**

(ii) A square shaped loop of side $\frac{l}{2}$ is initially lying outside a region of uniform magnetic field $\vec{B}$ as shown in the figure. The loop is moved towards right with a constant velocity $\vec{v}$ till it goes out of the region of magnetic field.



(I) What will be the directions of induced current when the loop enters the field and when it leaves the field ?

(II) Draw the plots showing the variation of magnetic flux ϕ linked with the loop with time t and variation of induced emf E with time t. Mark the relevant values of E, ϕ and t on the graphs. *5*

OR

#

(b) (i) Differentiate between peak and rms values of alternating current. How are they related ?

(ii) A current element X is connected across an ac source of emf $V = V_0 \sin 2\pi\nu t$. It is found that the voltage leads the current in phase by $\frac{\pi}{2}$ radian. If element X was replaced by element Y, the voltage lags behind the current in phase by $\frac{\pi}{2}$ radian.

(I) Identify elements X and Y by drawing phasor diagrams.

(II) Obtain the condition of resonance when both elements X and Y are connected in series to the source and obtain expression for resonant frequency. What is the impedance value in this case ? *5*