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# PHYSICS - Optional

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## Electricity and Magnetism 2015 - 2019

# UPSC – PHYSICS Optional – 2015 Questions

**1.** Under one-dimensional configuration, the charge density is given by $\rho(x) = \frac{\rho_o x}{5}$; where $\rho_o$ is a constant charge density. If the electric field. $|\vec{E}| = 0$ at $x = 0$ and potential V $= 0$ at $x = 5$, determine V and $|\vec{E}|$.

**[10M]**

**2.** A conducting sphere of radius 5 cm has a total charge of 12 nC uniformly distributed on its surface in free space. Determine the displacement vector $\vec{D}$on its surface and outside at a distance $r$ from the centre of the sphere.

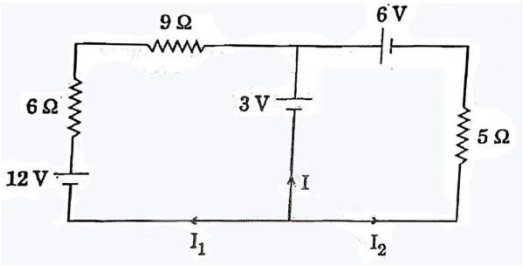
**[10M]**

**3.** A series RLC circuit has a resistance of 100 Ω and an impedance of 210 Ω. If this circuit is connected to an a. c. source with an r. m. s. voltage of 220 V, how much is the average power dissipated in the circuit? **[10M]**

**4.** A radio station transmits electromagnetic waves isotropically with an average power of 200 kW. Determine the average magnitude of the maximum electric field at a distance of 5 km from it. **[15M]**

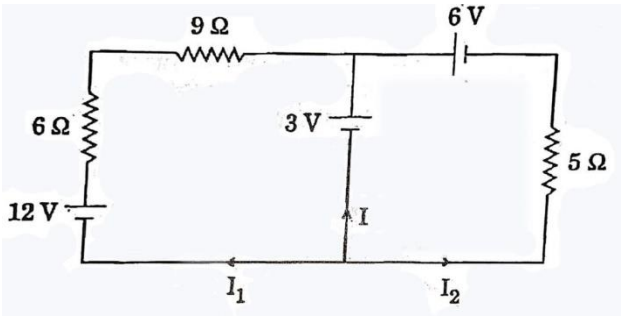
**5.** A series RLC circuit has $R = 2$ Ω. The energy stored in the circuit decreases by 1% per period of oscillation. Its natural undamped frequency is 2 kHz. Determine the values of indicator L and the quality factor. **[15M]**

**6.** In the circuit given below, find the values of currents $I_1, I_2$ and I. **[10M]**



# UPSC – PHYSICS Optional – 2016 Questions

**1.** In the circuit diagram shown below, the voltmeter reads 50 volts when it is connected across the 400 Ω resistance. Calculate what the same voltmeter will read when connected across the 300 Ω resistance. **[10M]**




**2.** With the help of a neat diagram, show that the potential due to a dipole at a point is given by $V = \frac{1}{4\pi\varepsilon_o} \cdot \frac{p\cos\theta}{r^2}$, where $p$ is the dipole moment of the charge distribution, θ is the angle between the line joining the centre of the dipole to the point of interest and the axis of the dipole. **[10M]**

**3.** An alternating current varying sinusoidally with a frequency of 50 Hz has an r. m. s. value of 40 A. Find the instantaneous value of the current at 0.00125 second after passing through maximum positive value. **[10M]**

**4.** Write down Maxwell's equations for linear dielctrics and deduce the equation of continuity. **[10M]**

**5.** State and prove Poynting's theorem. **[20M]**

**6.** Show that the displacement current between the plates of a parallel-plate capacitor is equal to the conduction current across the conductor. **[10M]**

**7.** A parallel plate capacitor is connected to a 240 V AC supply having angular frequency of 300 $rad/s$. Find the r. m. s. value of the conduction current in the circuit. What is the displacement current between the plates of the capacitor? Given, $C = 200$ pF. **[10M]**

# UPSC – PHYSICS Optional – 2017 Questions

**1.** Discuss the principle of 'artifical dielectric'. Where do you find its use? **[10M]**

**2.** How large an inductance needs to be connected in series with a $120\ \text{V}, 60\ \text{W}$ lightbulb if it is to operate normally when the combination is connected across a $240\ \text{V}, 60\ \text{Hz}$ supply? **[10M]**

**3.** A charge $q = 2\mu C$ is placed at $a = 10$ cm form an infinite grounded conducting plane sheet. Find the (i) total charge induced on the sheet, (ii) force on the charge $q$ and (iii) total work required to remove the charge slowly to an infinite distance from the plane. **[10M]**

**4.** When a person carrying something metallic walks through the doorway of a metal detector, it emits a sound. Explain the reason behind it. A $200\ \Omega$ resistor and a $15\ \mu F$ capacitor are connected in series to $220\ \text{V}, 50\ \text{Hz}$ a.c. supply. Calculate the current in the circuit and the r.m.s. voltage across the resistor and the capacitor. Is the algebraic sum of these voltages more than the supply voltage? If yes, resolve the paradox. **[15M]**

**5.** An aluminium foil of relative emittance 0.1is placed between two concentric spheres (assumed perfectly black) at temperatures 300K and 200K respectively. Find the temperature of the foil once the steady state is reached. **[15M]**

**6.** Write down the electromagnetic wave equations in non-conducting dilectric medium. Hence show that the velocity of wave propagation is given by $v = \sqrt{\frac{1}{\varepsilon\mu}}$, where the symbols have their usual meanings. **[10M]**

**7.** A current $i(t) = (2e^{-t} - e^{-2t})\mu A$ a 120 nF capacitor for a period of 2 seconds. If the final voltage across the capacitor is 15 V, what was the initial voltage across it? **[10M]**

**8.** (i) Why does a soap bubble expand upon electrification?

(ii) A sphere of radius R contains a charge $+Q$ and a charge $-Q$ distributed uniformly in the upper and lower hemispheres respectively. Show that the dipole moment of charge distribution is $\frac{3}{4}QRK$, where $\hat{k}$ is directed along the polar axis of the spherical coordinate system. **[15M]**

**9.** (i) Discuss briefly the features of 'guard rings'.

(ii) The plates of a capacitor are square shaped, each of side $l$. The plates are inclined at an angle $\alpha$ to each other. The smallest distance between the plates is $a$. Calculate the capacitance when $\alpha$ is small. **[15M]**

## UPSC – PHYSICS Optional – 2018 Questions

**1.** A current carrying circular wire loop of radius 1.0 cm has a magnetic moment 2.0 mJ/T. Determine the magnetic field at an axial distance of 3.0 cm from the centre of the loop. **[10M]**

**2.** A 12.0 V battery is connected at $t = 0$ to a series combination of a resistor $R = 10.0\Omega$ and an inductor $L = 5.0H$. At what rate is energy being stored in the inductor when the current in the circuit is 0.4 $A$? **[10M]**

**3.** Two solenoids have 500 and 800 turns of wire and are placed co-axially close to each other. A current of 5.0 $A$ in the first solenoid produces an average flux of 200 $\mu Wb$ through its each turn and a flux of 100 $\mu Wb$ through each turn of the second solenoid. Find the self-inductance of the first solenoid and the mutual inductance of the solenoids. **[10M]**

**4.** Write down Maxwell's equations in integral form. Explain the significance of each of these equations. **[05M]**

**5.** A parallel plate capacitor has plate area $= 4.0\ \text{cm}^2$ and plate separation 2.0 mm. An a.c. voltage $V = 20\sin(5 \times 10^3 t)$ volts is applied across the plates. If the dielectric constant of the medium between the plates is $e_r = 2.0$. Calculate the displacement current. **[05M]**

**6.** A 0.5 m long cylindrical medium between two conducting plates has uniform charge density of $100\ \text{nC/m}^3$. The axis of the cylindrical medium is along z-axis. The left plate is at $z = 0$ and has a potential of 10 kV and the right plate is grounded. Determine the electric field at axial distance $z = 0.2$ m. **[15M]**

**6.** A uniformly magnetized sphere of radius R has magnetization $\vec{M} = M_o\hat{Z}$. If the scalar magnetic potentials inside and outside the sphere are given as under $\phi_m = \frac{M_o}{3}Z\ ;\ r \le R$ and $\phi_m = \frac{M_o}{3}\frac{R^3}{r^2}\cos\theta;\ r > R$ where $r, \theta$ are two spherical coordinates, find the magnetic field inside and outside the sphere. **[15M]**



## UPSC – PHYSICS Optional – 2019 Questions

**1.** Why do we prefer to work with a critically damped ballistic galvanometer in a laboratory? What is external critical damping resistance? **[10M]**

**2.** Starting from the expression for the electrostatic potential $\phi(\vec{r}) = \frac{1}{4\pi\varepsilon_o}\int_V \frac{\rho(\vec{r_o})}{|\vec{r}-\vec{r_o}|}dV_o$ obtain Poisson's equation $\nabla^2\phi = -\frac{\rho}{\varepsilon_o}$ **[10M]**

**3.** Two conducting planes, intersecting at right angles to each other, are kept at a potential $\phi_o$. Calculate the potential at a point in space if the total charge on a plane of area $\alpha$ be Q. **[15M]**

**4.** Three cells are connected in parallel with similar poles connected together with wires having negligible resistance. The emfs of the cells are 2, 1 and 4 volts respectively and the corresponding internal resistances are 4, 3 and 2 ohms. Calculate the current flowing through the 4 V cell. **[15M]**

**5.** Find the values of E and H on the surface of a wire carrying a current. By computing the Poynting vector, show that it represents a flow of energy into the wire. **[20M]**