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IES

Engineering Services Examination - UPSC

ELECTRICAL ENGINEERING

Topic-wise Conventional

Papers I & II

1994 to 2013

Engineers Institute of India

28-B/7, Jia Sarai, Near IIT Hauz Khas New Delhi-110016

Tel: 011-26514888

Publication Link: www.engineersinstitute.com/publication

ISBN: 978-93-5137-756-6

Price: Rs. 80.00

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Dedicated to Electrical Engineers

and Engineering Services aspirants.

A word to the students

Er. R.K. Rajesh
(DIRECTOR)

Engineering services examination offers one of the most promising and prestigious careers for service to the nation. Over the past few years, it has become more competitive as a number of aspirants are increasingly becoming interested in government jobs due to decline in other career options.

In my opinion, ESE rigorously tests candidates' overall understanding of concepts, ability to apply their knowledge and personality level by screening them through various stages. A candidate is supposed to smartly deal with the syllabus not just mugging up concepts. Thorough understanding with critical analysis of topics and ability to express clearly are some of the pre-requisites to crack this exam. The syllabus and questioning pattern has remained pretty much the same over the years. Conventional paper practice is very important to score good marks, as it checks your writing skills, deep understanding of a subject.

Established in 2006 by a team of IES and GATE toppers, we at **Engineers Institute of India-E.i.i** have consistently provided rigorous classes and proper guidance to engineering students over the nation in successfully accomplishing their dreams. We believe in providing exam-oriented teaching methodology with updated study material and test series so that our students stay ahead in the competition. The faculty at EII are a team of experienced professionals who have guided thousands to aspirants over the years. They are readily available before and after classes to assist students and we maintain a healthy student-faculty ratio. Many current and previous year toppers associate with us for contributing towards our goal of providing quality education and share their success with the future aspirants. Our results speak for themselves. Past students of EII are currently working in various departments and PSU's and pursuing higher specializations. We also give scholarships to meritorious students.

A detailed solution of the past years conventional questions, prepared by toppers, will be available very soon.

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India's Best Institute for IES, GATE & PSUs

A Team of IES & GATE Toppers

ELECTRICAL ENGINEERING

ENGINEERING SERVICES EXAMINATION

CONVENTIONAL PAPER-I

(1994 to 2013)

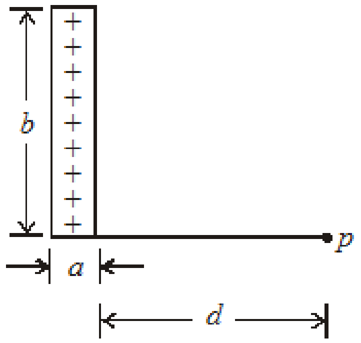
28-B/7, Jia Sarai, Near IIT, Hauz Khas, New Delhi-110016. Ph. 011-26514888. www.engineersinstitute.com

1 EM THEORY

1994 to 2013

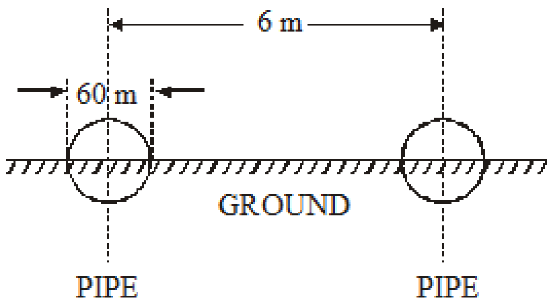
Paper-1994

(1.) (***a***) Figure shows a rectangular bus bar for distributing large currents. It is required to find magnetic field at the point 'P' located on *x*-axis, adjacent to the bus bar and directly opposite one edge of it. Show that the X and Y components of the resulting vector B are given by **(12)**



$$B_X = \frac{\mu_0 I}{4\pi b} \ln \frac{d^2 + b^2}{d^2} \quad \text{and} \quad B_Y = \frac{\mu_0 I}{2\pi b} \tan^{-1}\left(\frac{b}{d}\right)$$

(***b***) Two long parallel zinc plated iron pipes have a spacing of 6 m between centers. The pipes are half buried in the ground as shown in figure. The diameter of the pipes is 60 cms. The conductivity of the ground is 10^{-4} mho/meter. Find the resistance between the two pipes per meter length. **(12)**



(***c***) A spherical charge density distribution is given by

$$\rho = \rho_0\left(1 - \frac{r^2}{a^2}\right) \quad ; r \le a$$

$$= 0 \quad ; r > a$$

Using Poisson's and Laplace's equations as applicable, find E everywhere for $0 \le r \le \infty$. Show that maximum value of E occurs at $r = 0.745\, a$. **(12)**

(2.) (***a***) Obtain Maxwell's equation in the differential form as derived from Faradays Laws. **(12)**

(***b***) The electric field intensity of an electromagnetic wave in free space is given by

$$E_Y = 0, \qquad E_Z = 0, \qquad E_X = E_0 \cos\omega\left(t - \frac{Z}{\upsilon}\right)$$

Determine expression for the components of magnetic intensity $\bar{H}$. **(12)**

(***c***) A uniform plane electromagnetic wave is incident at an angle θ_1 at the surface of discontinuity between two homogeneous isotropic dielectrics with permittivity ε_1 and ε_2, ε_2 being the permittivity of the dielectric into which the wave gets refracted at an angle θ_2. If E_1 E_r and E_t are the electric intensities respectively of the incident, reflected and transmitted waves, show that the reflection co-efficient for parallel polarization is given by **(12)**

$$\frac{E_r}{E_i} = \frac{\tan(\theta_1 - \theta_2)}{\tan(\theta_1 + \theta_2)}$$

Paper-1995

(3.) (***a***) (*i*) State Maxwell's equation in differential form corresponding to Gauss's Law for electric fields. Starting from the Maxwell's equation in differential form, obtain the Poisson's equation for the general situation in which the permittivity of the medium is not constant and is a function of position.

(*ii*) Starting from the equation of continuity, show for a conducting medium obeying Ohm's law, $J = \gamma E$, and using Gauss's law, that

$$\frac{\partial \rho}{\partial t} + \frac{\gamma}{\varepsilon_o}\rho = 0$$

where ρ is the charge density. **(6, 6)**

(***b***) An infinite cylinder of radius ρ_1 has a charge distribution of the form

$$\rho v = \rho_{\_}\ e^{-\frac{\rho}{\rho t}}$$

Derive expressions for electric field and electostatic potential produced by this charge distribution. The potential ϕ is zero at the radius ρ_1. **(12)**

(***c***) State Biot-Savart Law in its integral form. Find the magnetic induction at any point on the line through the center, and perpendicular to the plane circular current loop.

(4.) (***a***) Obtain Maxwell's equations in integral and differential forms as derived from Faraday's Laws. **(12)**

(***b***) What do you understand by

(*i*) uniform plane wave (*ii*) linearly polarized wave, and

(*iii*) elliptically polarized wave?

The electric field intensity associated with a plane wave traveling in a perfect dielectric medium having $\mu = \mu_o$ is given by

$$E = 10\cos(6\pi 10^7 t - 0.4\,\pi Z)\, i_x \text{ V/m}$$

Find the phase velocity, the permittivity of the medium and associated magnetic field vector H. Velocity in free space = 3×10^8 m/sec. **(12)**

(*c*) Define, in relation to traveling waves, the following:
(*i*) Reflection co-efficient (*ii*) Transmission co-efficient, and
(*iii*) Standing wave ratio
An electric field wave traveling in air is incident normally on a boundary between air and dielectric having permeability μ_o and relative permittivity $\varepsilon_r = 4$. Prove that one-ninth of the incident power is reflected and eight ninth of it transmitted into the second medium. **(12)**

Paper-1996

(5.) **(*a*)** Define magnetic vector potential. **(12)**
Derive an expression for the mutual inductance between two straight parallel wires of length L, using magnetic vector potential.

(*b*) (*i*) A straight wire of length L is charged with electricity of amount *q* per unit length. This is placed near an earthed conducting sphere of radius *r*. The center of the sphere is at a perpendicular distance '*s*' from the wire. The ends of the wire are equidistant from the center of the sphere. Find the charge on the sphere. Assume that the distribution of charge on the wire is unaffected by induction. **(8)**
(*ii*) What is the skin depth of current penetration in copper at a frequency of 10^4 MHz. If the resistivity is 1.7×10^{-6} ohm-cm. **(4)**

(*c*) Show with usual notations, that
$$\bar{\nabla} \times \text{H} = \bar{\text{J}}_c + \frac{\partial \bar{\text{D}}}{\partial t}$$
Find $\bar{\nabla} \times \bar{\text{H}}$ if the field is varying harmonically. **(12)**

(6.) **(*a*)** Derive the Helmholtz equation for $\bar{\text{E}}$ in the form
$$\bar{\nabla}^2\, \bar{\text{E}} - \mu\sigma \frac{\partial \bar{\text{E}}}{\partial t} - \mu\varepsilon \frac{\partial^2 \text{E}}{\partial t^2} = 0$$
The electric field intensity associated with a plane wave traveling in a perfect dielectric medium is given by
$$\text{E}_x(z, t) = 12 \cos(2\pi \times 10^7 t - 0.1\pi x) \text{ V/m}$$
Find:
(*i*) Velocity of propagation (*ii*) Intrinsic impedance **(12)**

(*b*) Explain what you understand by Perpendicular polarization and Parallel polarization.
Given two dielectric mediums, medium 1 is free space and medium 2 has $\varepsilon_2 = 4\varepsilon_0$ and $\mu = \mu_0$. Determine reflection coefficient for oblique incidence $\theta_1 = 30°$ for
(*i*) Perpendicular polarization (*ii*) Parallel polarization **(12)**

(*c*) Derive from the Maxwell's equations, the pointing theorem, and explain the physical significance of the terms involved. **(12)**

Paper-1997

(7.) **(*a*)** (*i*) Show that the electromagnetic energy due to charged conductors in space is given by

$$\frac{1}{2}\int_V \bar{D}\,.\,\bar{E}\,dv$$

where field $\bar{D}$ and $\bar{E}$ occupy whole of the space. **(8)**

(*ii*) A square metal plate of 0.2 m side is suspended from one of the arms of a balance such that it is parallel to another fixed horizontal plate of same dimension 1.0 mm below it. What should be the mass placed in the other arm of the balance to maintain the separation on applying 100 V across plates? **(4)**

(*b*) The plane X = 0 separates two isotropic linear homogeneous magnetic materials. If relative permittivity is 5 for $x > 0$ and 2 for $x < 0$ and

for $\quad x < 0, \dfrac{\bar{B}}{\mu_0} = -2\bar{i}_x + 3\bar{i}_y - \bar{i}_z$

find $\bar{H}$ and $\bar{m}$ for $x > 0$.

What will be these values if there is a surface current density

$J = 2i_y$ A/ m

on the plane $x = 0$? **(12)**

(*c*) The electric field intensity of an e.m. wave at the origin of the spherical co-ordinate system is given by

$$\bar{E} = \frac{E_0}{r}\sin\theta\cos(\omega t - \beta r)\,i_\phi; \qquad \beta = \omega\sqrt{\mu_0\,\varepsilon_0}$$

Find

(*i*) associated magnetic field (*ii*) Poynting vector

(*iii*) power over a spherical surface of radius *r* around the origin. **(12)**

(8.) **(*a*)** (*i*) A sheet charge of uniform density ρ_s extends in the entire X-Y plane. Show that Gauss's law in differential form for the entire sheet charge is given by

$\nabla\,\bar{F} = \dfrac{1}{\varepsilon_0}\rho_s\;\delta(z); \delta(z)$ is Dirac delta function. **(4)**

(*ii*) Obtain Green's integral identities and state their significance. Apply first identity to show that the specifications of both divergence and curl of a vector with boundary conditions are sufficient to make the function unique. **(8)**

(*b*) (*i*) A parallel plate capacitor has rectangular plates of area A, but plates are not exactly parallel. The separation at one edge is $(d - a)$ while at the other is $(d + a)$; $a << d$. Show that the capacitance is given approximately by $\quad C = \dfrac{\varepsilon_0 A}{d}\left(1 + \dfrac{a^2}{3d^2}\right)$ **(8)**

(*ii*) Show that the vector potential due to moving point charge *q* at a distance R is given by

$\bar{A}(r) = \dfrac{\mu_0}{4\pi}\dfrac{q\bar{v}}{R}; \bar{v}$ being velocity of charge. **(4)**

(*c*) The electric field intensity associated with a plane e.m. wave along any direction in free space is given by

$$\overline{E}(r) = \frac{1}{2}[(-2\sqrt{3} - j)\overline{a}_x + (Z\, j\sqrt{3})a_y + j2\sqrt{3}\,\overline{a}_z]\,\varepsilon^{-j-\frac{\pi}{5}(\sqrt{3}x+3y+2z)}$$

Find

(*i*) direction of wave propagation

(*ii*) frequency and wavelength

(*iii*) apparent wavelengths and phase velocities along three axes. **(12)**

Paper-1998

(9.) (***a***) What do you understand by irrotational fields? State the properties of a static electric field. Find whether the following fields are realizable as static fields:

(*i*) $\overline{F}_1 = \frac{1}{yz}(y\,\overline{i}_x - x\,\overline{i}_y)$

(*ii*) $\overline{F}_2 = k(\cos\phi\,\overline{i}_r + \sin\phi\,\overline{i}_\phi)$ – cylindrical co-ordinates. **(8)**

(***b***) Show that Ampere's law for steady currents is not applicable for time varying currents. Hence explain the concept of displacement current and its intensity.

Find the displacement current through a surface at a radius $r(a < r < b)$ in a co-axial cylindrical capacitor of length l when a voltage $v = V_m \sin\omega t$ is applied; a and b being radii of inner and outer cylinders respectively. **(12)**

(***c***) State Maxwell's equations for harmonically varying fields and deduce the wave equation in a conducting medium. **(10)**

Discuss the significance of depth of penetration and skin effect. **(6)**

(10.) (***a***) (*i*) Deduce Laplace equation in spherical co-ordinates and find whether the potential field $V = \frac{a}{r^3}\sin\theta$ volts in a region of free space satisfied it. **(6)**

(*ii*) A slab of relative permittivity 6 and thickness 10 mm partially fills the space between two the capacitor so formed is 15 kV, find force on the slab to push it inside the plates. **(6)**

(***b***) Define and distinguish between Brewster angle and critical angle with reference to an electromagnetic wave incident on a separating surface between two perfect dielectrics. Show that critical angle is normally greater than Brewster angle.

A perpendicularly polarized e.m. wave is incident on a surface $(\mu_r = 1; \varepsilon_r = 10)$ separating glass from air. Find the critical angle. If the magnitude of the electric field of the incident wave is 1 V/m and the incident angle is 45º, find the magnitude of the field at the separating surface in air. **(12)**

(***c***) Deduce Poynting theorem in complex form and discuss its significance. **(12)**

Paper-1999

(11.) (*a*) Determine the force exerted per meter by a 2 mm dia conductor of infinite length on a similar parallel conductor 1 m away, when a potential of 1000 V is existing between them. Make suitable assumptions about other details you need, and state them. **(12)**

(*b*) Derive Laplace's equation pertaining to electrostatic potential distribution in a charge free space. Show how this is useful in computing the potential distribution in a two-dimensional electrostatic problem using a digital computer. **(12)**

(*c*) The electron gun of a TV display tube emits electrons almost at zero velocity. These are accelerated through an electric field of 1000 V/cm over a distance of 5 cm. They then pass through a vertical deflecting coil producing a flux density of $0.01\ \text{Wb/m}^2$ over a distance of 1 cm. If the screen is at a distance of 10 cm from the center of the deflecting system calculate the deflection produced (charge per unit mass for electrons is 1.759×10^{11} C/kg). **(12)**

(12.) (*a*) (*i*) Using Maxwell's equations, derive equations to demonstrate the propagation of uniform plane waves in a perfect dielectric medium.

(*ii*) The magnetic field intensity H of a plane wave is free space is 0.20 A/m and is in the Y-direction. If the wave is propagating in the Z-direction with a frequency of 3 GHz, find the wavelength, amplitude and direction of the E-vector, $\mu_0 = 4\pi\times10^{-7}\ \text{H/m}$ and $\varepsilon_0 = 8.85\times10^{-12}\ \text{F/m}$. **(12 + 12)**

(*b*) Discuss the wave propagation in

(*i*) a lossy dielectric; (*ii*) a conductor

Derive relevant equations. **(12)**

Paper-2000

(13.) (*a*) State Gauss's law and develop its mathematical form. Give two examples of its applications. **(12)**

(*b*) For $\overline{F} = xy^2\,\overline{a}_x + yz^2\overline{a}_y + 2x\,z\,\overline{a}_z$, calculate the line integral $\int_C \overline{F}.\overline{dl}$ where C is the straight line between points (0, 0, 0) and (1, 2, 3). **(12)**

(*c*) The permittivity of the dielectric material between the plates of a parallel plate capacitor varies uniformly from ε_1 at one plate to ε_2 at other plate. Show that the capacitance is given by

$$C = \frac{A}{d}\,\frac{\varepsilon_2 - \varepsilon_1}{\log_e\left(\dfrac{\varepsilon_2}{\varepsilon_1}\right)}$$

where A and *d* are the area of each plate and separation between the plates respectively. **(12)**

(14.) (*a*) Obtain by means of Laplace's equation, the potential distribution between two coaxial conducting cylinders of radii *a* and *c* with dielectric of constant ε_1 filling the region between *a* and *b* and a second dielectric of constant ε_2 filling the region between *b* and *c*. Given: $c > b > a$. **(12)**

(*b*) From Maxwell's curl equations derive the wave equation in E for a plane wave traveling in the positive Y-direction in an isotropic homogeneous loss-less medium. The electric field is in Z-direction.
Assuming harmonic variation, state a solution of this equation and prove that it is a solution. **(12)**

(*c*) Define in relation to traveling waves, the following: **(12)**
(*i*) Reflection coefficient (*ii*) Transmission coefficient
(*iii*) Standing-wave ratio.

Paper-2001

(15.) (*a*) State and explain Gauss's law. A spherical volume charge distribution ρ is given by

$$\rho = \rho_0 \left(1 - \frac{r^2}{100}\right) \quad \text{for } r \le 10 \text{ mm}$$
$$= 0 \quad \text{for } r > 10 \text{ mm}$$

Show that the maximum value of electric field intensity E occurs at r = 7.45 mm. Obtain the value of E at r = 7.45 mm. **(12)**

(*b*) Define Poynting's vector and Poynting's theorem. Show that ratio of Poynting's vector to energy density is $\le 3 \times 10^8$ m/s. **(12)**

(*c*) Explain traveling waves on a transmission line and define Standing Wave Ratio (SWR). A high frequency loss-less transmission line has a characteristic impedance of $600\,\Omega$. Calculate the value of current SWR when the load is $(500 + j300)\,\Omega$. **(12)**

(16.) (*a*) A long straight cylindrical wire of radius 2 mm is placed parallel to a horizontal plane conducting sheet. The axis of the wire is at a height of 100 mm above the sheet. Calculate the stress in the medium at the upper surface of the sheet just vertically below the wire. The potential difference between the wire and sheet is 3.3 kV. Derive any formula used and state assumptions made. **(12)**

(*b*) "A handy 'curl meter' in the form of a pin wheel is used to indicate curl of a vector field." Justify the statement. **(12)**

(*c*) Two infinite and conducting cones both on *z*-axis, one is $\theta = \theta_1 = 45^\circ$ (constant) cone and the other is in $\theta = \theta_2 = 150^\circ$ (constant) cone. The region between them is characterized by $\varepsilon, \rho_v = 0, V = 0$ at θ_1 and V = 10 V at θ_2. Find the expression for V between $45^\circ < \theta < 150^\circ$. **(12)**

Paper-2002

(17.) (*a*) A sheet of charge, $\rho_s = 2$ nc/m^2 is present at the plane x = 3 in free space, and a line charge, $\rho_L = 20$ nc/m is located at x = 1, z = 4. Find
(*i*) the magnitude of the electric field intensity $\bar{E}$ at the origin
(*ii*) the direction of $\bar{E}$ at (4, 5, 6)
(*iii*) the force per metre length on the line charge. **(12)**

(***b***) If V in the free space is given by

$V = 60 \sin \frac{\theta}{r^2}$, and a point P is located at $r = 3$m, $\theta = 60°$, $\phi = 25°$, find at P.

(*i*) V_P (*ii*) $\bar{E}_P$ (*iii*) $\frac{dV}{dN}$ (*iv*) $\bar{a}_N$ (*v*) ρ_r

(***c***) Conducting cylinders at $\rho_1 = 1.6$ cm and $\rho_2 = 5$ cm in free space are held at potentials of 80 V and –40 V, respectively.
Find

(*i*) V and $\bar{E}$ at $\rho = 2$ cm (*ii*) the surface at which V = 0

(*iii*) Capacitance per meter length between the conducting cylinders. **(12)**

(18.) (***a***) A coaxial cable carries uniformly distributed current I in the inner conductor and –I in the outer conductor. Determine magnetic field intensity distributions within and outside the coaxial cable by using Ampere's circuital law. **(12)**

(***b***) In a region where $\varepsilon_R = \mu_R = 1$ and $\sigma = 0$,

$\bar{A} = 10^{-3}\, y \cos 3\times10^8 t \cos Z\, \bar{a}_z$ Wb/ m,

$V = 3\times10^5\, y \sin 3\times10^8 t \sin ZV$

Find $\bar{E}$ and $\bar{H}$. **(12)**

(***c***) A transmission line operating at 500 M rad/sec has L = $0.5\,\mu$H/ m, C = 32 pF/m, G = $100\,\mu$℧m and R = $25\,\Omega$/ m. Calculate $\gamma, \alpha, \beta, v, \lambda$ and z_o. **(12)**

Paper-2003

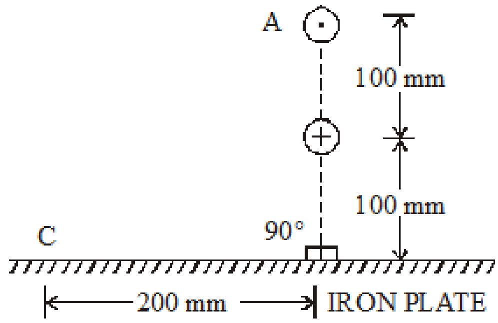
(19.) (***a***) Three parallel transmission wires are charged with linear densities (+) 2D, (–) D and (–) D in coulomb per meter length respectively. Obtain the condition for points on equipotential surfaces inside the parallel wires. Hence or otherwise show that, if three wire sections occupy the corners of an equilateral triangle then along the centroid axis over the whole length potential V = 0. Explain briefly the formula used. **(12)**

(***b***) Explain dipole moment. A dielectric slab of flat surface with relative permittivity of 5 is disposed with its normal to a uniform field with flux density 2.0 coulombs per m^2. The volume of the slab is $0.1\, m^3$. It is uniformly polarized. Calculate its dipole moment. **(12)**

(***c***) Calculate the value of capacitance of a spherical capacitor consisting of two concentric spheres of radii 60 mm and 80 mm with air as dielectric medium between the two. Derive the formula used. **(12)**

(20.) (***a***) A long fluid conductor of circular cross-section of radius 50 mm and relative permeability 1.005 carries an electric current of 100 A. Calculate the pressure at the center of the conductor. Derive the formula used. **(12)**

(***b***) Two long thin parallel conductors perpendicular to the plane of the paper and parallel to the surface of an infinite iron plate of high permeability, each carrying a steady current of 100 A in opposite directions are shown in figure.



Calculate the magnetic field strength at a point C, 200 mm away from the bottom point on iron plate below the conductors. Also calculate the mechanical force per unit length on the conductor A. **(12)**

(*c*) The electric field intensity associated with a plane wave traveling in a perfect dielectric medium $(\mu_r = 1)$ is given by

$$E_x(z,t) = 14.14\cos\left(2\pi\times10^7 t - \frac{\pi z}{10}\right)$$

in volts per meter. Calculate the values of velocity of propagation and intrinsic impedance. **(12)**

Paper-2004

(21.) (*a*) Two parallel wires each of 3 meters length having a separation of 4 mm. Calculate the forces exerted on each of these wires when they carry a current of 5A in the same direction and opposite direction. Assume $\mu_0 = 4\pi\times10^{-7}$ H/m. **(12)**

(*b*) Prove that the capacitance between two lines is given by **(12)**

$$C = \frac{\pi\,\varepsilon_0}{\ln\left(\frac{d}{r}\right)}$$

where d is the distance of separation between these lines and r is radius of each line.

(*c*) Draw a map of the electric field intensity of a charged conductor running parallel to an infinite conducting plane using method of electrical images. **(12)**

(22.) (*a*) Make statements about tangential components of E and H, and normal components of B and D at any surface of discontinuity. Derive Maxwell's equation for harmonically varying fields in integral and differential forms.

For coaxial capacitor (having outer radius *b*, inner radius a and length *l*), find the displacement current flowing across a surface at a radius *r* between *a* and *b*. Assume $V = V_{max}\sin\omega t$. **(12)**

(*b*) Derive wave equations for a conducting medium. A concentric cable has a d.c. voltage V between conductors and steady current I flowing in inner and outer conductors. Power is being transferred to a load resistance R along the concentric cable. Inner conductor has radius *a* and outer conductor has radius *b*. Find value of magnetic field strength H directed in circles about the axis. Also find the electric field strength E directed radially. Show that total power flow along cable is given by the integration of Poynting vector over any cross-sectional area. **(12)**

(*c*) For transmission lines equations

$$\frac{d^2 V}{d Z^2} = r^2 V \quad \text{and} \quad \frac{d^2 I}{d Z^2} = r^2 I$$

find the solution in exponential and hyperbolic function form. Prove that $Z_{SC} \cdot Z_{OC} = Z_O^2$

How impedance matching is done by means of stub lines? **(12)**

Paper-2005

(22.) (*a*) Explain the concept of wave impedance for plane waves traveling in a loss-less medium and show how this may be extended to cover the case of a conductive medium.

Show that the reflection coefficient for plane waves traveling in a vacuum and falling with normal incidence upon a medium having wave impedance η is given by

$$\frac{(\eta - \eta_0)}{(\eta + \eta_0)}.$$

Show that when a plane wave is incident normally upon a medium with permeability μ_0, permittivity ε_0 and conductivity σ the fraction of power absorbed is approximately $2\left(\frac{2\omega\varepsilon_0}{\sigma}\right)^{\frac{1}{2}}$. **(12)**

(*b*) Derive an expression for characteristic impedance of a coaxial transmission line with inner and outer radius are *a* and *b* respectively. **(12)**

(*c*) Show that in a source free homogeneous isotropic linear medium, the time harmonic electric and magnetic fields are given by

$$E = -\nabla \times F + \frac{\nabla(\nabla . A)}{j\omega\varepsilon} - j\omega\mu A$$

and

$$H = \nabla \times A + \frac{\nabla(\nabla . F)}{j\omega\mu} - j\omega\varepsilon F$$

where A and F are magnetic and electric vector potential. **(12)**

(23.) (*a*) Write the Maxwell's equation in a good conductor for time harmonic fields. Show that the conduction current density J in a good conductor must satisfy

$\nabla(\nabla . J) - \nabla^2 J = -j\omega\mu\sigma J$ **(12)**

(*b*) Explain relaxation time constant for a metal. Derive an expression for the continuity of current equation for dynamic current. Show that the volume change density is a solution of $\frac{\partial \rho_v}{\partial t} + \left(\frac{\sigma}{\varepsilon}\right)\rho_v = 0$ **(12)**

(*c*) Show that for metals

$$\eta = \sqrt{\frac{\omega\mu}{2\sigma}}\,(1 + j) \qquad k = \sqrt{\frac{\omega\mu\sigma}{2}}\,(1 - j)$$

where η is intrinsic wave impedance of the medium and *k* is the wave number.

(12)