Mark Scored:

KATHMANDU UNIVERSITY
End of Semester Examination
August/September, 2017

Level : B. Sc.
Year : III

Course : PHYS 313
Semester : II

Exam Roll No. :

Time: 30 min

F. M. : 20

Registration No.:

Date : SEP 0 3 2017

SECTION "A"

[20 Q × 1 = 20 marks]

Choose and tick the most appropriate answer.

1. The force of attraction between a point charge Q and a grounded infinite conducting plane at a distance d from the charge is numerically equal to

[a] $\frac{1}{4\pi\varepsilon_o}\frac{Q^2}{d^2}$ [b] $\frac{1}{4\pi\varepsilon_o}\frac{Q}{d^2}$ [c] $\frac{1}{8\pi\varepsilon_o}\frac{Q^2}{d^2}$ [d] $\frac{1}{16\pi\varepsilon_o}\frac{Q^2}{d^2}$

2. Under the integral sign, Dirac delta function $\delta(kx)$ (where k is non-zero constant) serves the same purpose as

[a] $|k|\delta(x)$ [b] $\frac{1}{|k|}\delta(x)$ [c] $\delta(x)$ [d] $\frac{|k|}{\delta(x)}$

3. The electric field due to short dipole varies as

[a] $\frac{1}{r}$ [b] $\frac{1}{r^2}$ [c] $\frac{1}{r^3}$ [d] $\frac{1}{r^4}$

4. The electric potential at any point r $(r > R)$ of conducting sphere of radius R in uniform electric field $\vec{E}_o$ is given by $V(r) = -\left(1 - \frac{R^3}{r^3}\right)E_o r\cos\theta$. The induced surface charge density is

[a] $-\varepsilon_o E_o \cos\theta$ [b] $\varepsilon_o E_o \cos\theta$ [c] $\varepsilon_o E_o \sin\theta$ [d] $2\varepsilon_o E_o \cos\theta$

5. The interaction potential energy of the two equal dipoles of dipole moment $\vec{p}$ lying along the line joining their centre and separated by distance d is

[a] $-\frac{1}{4\pi\varepsilon_o}\frac{p^2}{d^2}$ [b] $-\frac{1}{4\pi\varepsilon_o}\frac{2p^2}{d^2}$ [c] $\frac{1}{4\pi\varepsilon_o}\frac{p^2}{d^2}$ [d] $\frac{1}{4\pi\varepsilon_o}\frac{2p^2}{d^2}$

6. The magnetic vector potential $\vec{A} = \frac{\mu_o}{4\pi}\int\frac{\vec{J}}{r}d\tau$ is equivalent to

[a] $\vec{A} = \frac{\mu_o}{4\pi}\int\frac{Id\ell}{r^2}$ [b] $\vec{A} = \frac{\mu_o}{4\pi}\int\frac{\vec{K}d\ell}{r}$ [c] $\vec{A} = \frac{\mu_o I}{4\pi}\int\frac{d\ell}{r}$ [d] $\vec{A} = \frac{\mu_o}{4\pi}\int\frac{\vec{J}ds}{r}$

7. The magnetic scalar potential (ϕ_m) is defined as

[a] $\frac{\mu_o I}{4\pi\omega}$ [b] $\frac{\mu_o I\omega}{4\pi}$ [c] $\frac{I\pi\omega}{4\mu_o}$ [d] $\frac{\pi\omega\mu_o}{4I}$

8. Maxwell modified the Ampere's law ($\nabla\times\vec{B}=\mu_o\vec{J}$) by using the concept of displacement current. The displacement current ($\vec{J}_d$) is given by

[a] $\mu_o\frac{\partial\vec{E}}{\partial t}$ [b] $\varepsilon_o\frac{\partial\vec{E}}{\partial t}$ [c] $\varepsilon_o\mu_o\frac{\partial\vec{E}}{\partial t}$ [d] $\frac{1}{\varepsilon_o\mu_o}\frac{\partial\vec{E}}{\partial t}$

9. When a plane electromagnetic wave enters from one medium to another, the property that remains unchanged is

[a] amplitude [b] frequency [c] wavelength [d] velocity

10. The electric field in terms of potential functions $\vec{A}$ and φ is given by

[a] $-\nabla\phi+\frac{\partial\vec{A}}{\partial t}$ [b] $-\nabla\vec{A}-\frac{\partial\phi}{\partial t}$

[c] $-\nabla\phi-\frac{\partial\vec{A}}{\partial t}$ [d] $\nabla\vec{A}-\frac{\partial\phi}{\partial t}$

11. In plane electromagnetic wave the ratio of electric to magnetic vector $\left|\frac{\vec{E}}{\vec{H}}\right|$ is

[a] $\sqrt{\varepsilon_o\mu_o}$ [b] $\frac{1}{\sqrt{\varepsilon_o\mu_o}}$ [c] $\sqrt{\frac{\varepsilon_o}{\mu_o}}$ [d] $\sqrt{\frac{\mu_o}{\varepsilon_o}}$

12. In the region of the space where there is no charge or current, the curl of curl of electric field $\vec{E}$ is equal to

[a] $\mu_o\frac{\partial^2\vec{E}}{\partial t^2}$ [b] $\varepsilon_o\frac{\partial^2\vec{E}}{\partial t^2}$ [c] $\frac{1}{\varepsilon_o\mu_o}\frac{\partial^2\vec{E}}{\partial t^2}$ [d] $\varepsilon_o\mu_o\frac{\partial^2\vec{E}}{\partial t^2}$

13. The Maxwell's fourth equation in material medium can be written as

[a] $\nabla\times\vec{B}=\vec{J}_f+\frac{\partial\vec{D}}{\partial t}$ [b] $\nabla\times\vec{H}=-\vec{J}_f+\frac{\partial\vec{D}}{\partial t}$

[c] $\nabla\times\vec{H}=\vec{J}_f+\frac{\partial\vec{E}}{\partial t}$ [d] $\nabla\times\vec{H}=\vec{J}_f+\frac{\partial\vec{D}}{\partial t}$

14. The skin depth for a material with conductivity $5.8\times10^7\,\Omega/m$ and permeability $4\pi\times10^{-7}\,H/m$ at frequency of one mega cycle $(2\pi\times10^6\,c/s)$ is

[a] 0.066 mm [b] 0.66 mm [c] 6.60 mm [d] 66.6 mm

15. An air filled rectangular waveguide has cross-sectional dimension a =10 cm and b = 5 cm. The cut-off frequency (ω_{nm}) of the TE_{11} (transverse electric) mode is

[a] 22.36πc [b] 5.477πc [c] 500πc [d] 125πc

16. One dimensional Dirac delta function can be pictured as an infinitely high, infinitely thin spike at origin. The total area under the spike is____________

17. The infinitesimal volume element in spherical polar coordinate (r,θ,φ) is equal to_________

18. The electromagnetic field in which the component of magnetic field (H_z) is present and that of electric field is absent (i.e. E_z = 0) in the direction of propagation is called ____________

19. The energy per unit time per unit area transported by electromagnetic field is called_______________

20. If the reflection coefficients for normal and parallel components of reflected light are 0.09337 and 0.00851, then the degree of polarization is________________

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F. M. : 55

SECTION "B"
[5Q × 4 = 20 marks]

Attempt *ALL* questions.

1. A point charge Q is placed at a distance d from the centre of grounded conducting sphere of radius R. Calculate the induced charge and its position from the centre of sphere.

2. Show that $\oint(\vec{c}\cdot\vec{r})d\vec{\ell} = \vec{a}\times\vec{c}\oint$ for any constant vector $\vec{c}$.

OR

Find an expression for potential and induced surface charge density for a conducting sphere at fixed potential V_0 placed near the point charge Q.

3. Using Maxwell's equations $\nabla\cdot\vec{D} = \rho$ and $\nabla\times\vec{H} = \vec{J} + \frac{\partial\vec{D}}{\partial t}$, prove that, $\vec{F} = \frac{1}{4\pi\varepsilon_o}\frac{QQ_o}{r^3}\vec{r}$ and $\nabla\cdot\vec{J} = -\frac{\partial\rho}{\partial t}$.

4. Show that electromagnetic field vectors $\vec{E}$ and $\vec{H}$ are perpendicular to the direction of propagation of wave vector $\vec{K}$.

OR

Show that the attenuation constant (α_g) is equal to the ratio of power loss per unit length to twice the power transmitted through the guide.

5. Define gauge transformation and hence show that $\vec{E}$ and $\vec{B}$ exhibit gauge invariance.

SECTION "C"
[5Q × 7 = 35 marks]

Attempt *ALL* questions.

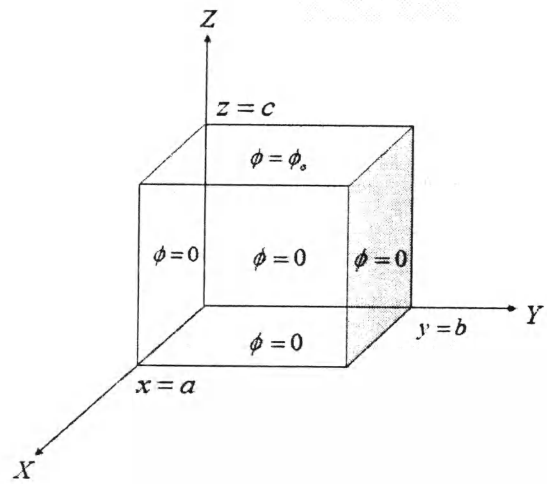
6. Obtain the Green's first and second identity and applying Green's second identity, show that the potential at any point within the volume V can be expressed as

$$\phi(x) = \frac{1}{4\pi\varepsilon_o}\int_V \frac{\rho}{r}d^3r + \frac{1}{4\pi}\oint_S\left[\frac{1}{r}\frac{\partial\varphi}{\partial n} - \varphi\frac{\partial}{\partial n}\left(\frac{1}{r}\right)\right]ds.$$

7. State and prove the Poynting theorem and then show that the Poynting vector $\vec{S}$ satisfies the continuity equation $\nabla\cdot\vec{S} = -\frac{\partial}{\partial t}(U_{mech} + U_{em})$, where U_{mech} and U_{em} are mechanical and electromagnetic energy densities respectively.

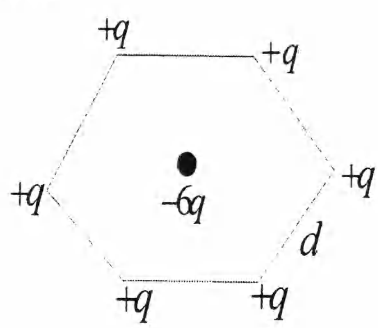
OR

Find the potential inside the rectangular conducting box for which all sides except one side $z = c$ having potential ϕ_o are grounded as shown in figure below by separation of variable method.



8. Starting from the equations of electric and magnetic vectors $(\vec{E}_o + \vec{E}''_o)\times\hat{n} = \vec{E}'_o \times \hat{n}$ and $(\vec{H} + \vec{H}'')\times\hat{n} = \vec{H}'\times\hat{n}$, derive Fresenel's equation for non-conducting media when electric field vector is perpendicular to the plane of incidence.

9. A charge of $+q$ coulomb is placed at every corner of a regular hexagon of side d and a charge of -6q is placed at the centre as shown in the figure below. Calculate the monopole, dipole and quadrupole moments. Also find the potential and field at a large axial distance from the charge distribution.



10. (a) Find the magnetic vector potential and magnetic induction for a long current carrying wire.
(b) Show that the magnetic vector potential for two long straight wires carrying a same current I in opposite direction is given by

$$\vec{A} = \frac{\mu_o I}{2\pi}\log\left(\frac{R_2}{R_1}\right)\hat{n}.$$

OR

What are TE and TM mode waves? Obtain the solution of an electromagnetic wave which is propagating in a rectangular waveguide in TM mode along z-axis. Also show that the cut-off frequency in TM mode is

$$\omega_{nm} = \pi c\sqrt{\left(\frac{n}{a}\right)^2 + \left(\frac{m}{b}\right)^2},$$

where symbol carry their usual meanings.