KATHMANDU UNIVERSITY
End Semester Examination
May/June, 2022

Marks Scored:

Level : B.E./B.Sc./B.Tech.
Year : I
Course : PHYS 102
Semester: II
Exam Roll No.:
Time: 30 mins.
F.M. : 15
Registration No.:
Date :

SECTION "A"
[15Q × 1 = 15 marks]

Choose and tick the most appropriate answer. The symbols, unless mentioned otherwise, have their usual meanings.

1. Suppose, we have a function of three variables –say, the temperature $T(x, y, z)$ in a room. Which one of the following statements is **NOT CORRECT?**
   [a] ∇T is a vector quantity.
   [b] The gradient ∇T points in the direction of maximum increase of the function T.
   [c] The curl of gradient is always zero: $\nabla\times(\nabla T)=0$.
   [d] The Laplacian of T is a vector quantity.

2. Two concentric imaginary spherical surfaces of radius R and $2R$ respectively surround a positive point charge $-Q$ located at the center of the surfaces. When compared to the electric flux Φ_1 through the surface of radius R, the electric flux Φ_2 through the surface of radius $2R$ is
   [a] $\Phi_2=\frac{1}{4}\Phi_1$ [b] $\Phi_2=\frac{1}{2}\Phi_1$ [c] $\Phi_2=\Phi_1$ [d] $\Phi_2=2\Phi_1$

3. The amount of work required to assemble four identical charged particles of magnitude Q at the corners of a square of side R is
   [a] $\frac{Q^2}{R}\left(4+\frac{1}{\sqrt{2}}\right)$ [b] $\frac{1.35}{\varepsilon_0}\frac{Q^2}{R}$ [c] $\frac{0.43}{\varepsilon_0}\frac{Q^2}{R}$ [d] $\frac{0.43}{\varepsilon_0}\frac{Q^2}{R^2}$

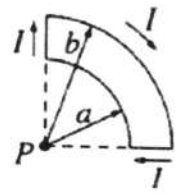
4. The **Clausius-Mossotti** equation tells you how to calculate the susceptibility χ_e of a nonpolar substance, in terms of the atomic polarizability α. The relation between the susceptibility χ_e and the atomic polarizability α is given by
   [a] $\chi_e=\frac{N\alpha/\varepsilon_0}{1-N\alpha/3\varepsilon_0}$ [b] $\chi_e=\frac{N\alpha/\varepsilon_0}{1+N\alpha/3\varepsilon_0}$ [c] $\chi_e=\frac{3\varepsilon_0}{N}\left(\frac{\alpha-1}{\alpha+2}\right)$ [d] $\chi_e=\frac{3\varepsilon_0}{N}\left(\frac{\alpha}{\alpha+2}\right)$

5. The unit of magnetization is
   [a] ampere meter
   [b] ampere per meter
   [c] farad meter squared
   [d] coulomb per meter squared

6. A 10-mH inductor is connected in series with a 10-ohm resistor, a switch and a 6-volt battery. How long after the switch is closed, will the current reach 99 percent of its final value?
   [a] 0.46 ms [b] 4.6 ms [c] 46 ms [d] 460 ms

7. Equal charges, one at rest, the other having a velocity of 10^4 m/s, are released in a uniform magnetic field. Which charge has the largest force exerted on it by the magnetic field?
   [a] The charge that is at rest.
   [b] The charge that is moving, if its velocity is parallel to the magnetic field direction when it is released.
   [c] The charge that is moving if its velocity makes an angle of 45^o with the direction of the magnetic field when it is released.
   [d] The charge that is moving if its velocity is perpendicular to the magnetic field direction when it is released.

8. What is the magnitude of the magnetic field at point P if $a = R$ and $b = 2R$?



   [a] $\frac{\mu_0 I}{6R}$ [b] $\frac{\mu_0 I}{16R}$ [c] $\frac{\mu_0 I}{12R}$ [d] $\frac{3\mu_0 I}{16R}$

9. Which one of the following statements is **CORRECT**?
   [a] The statement established by Maxwell is a changing electric field induces a magnetic field.
   [b] The term $\frac{1}{\mu_0}\left(\vec{E}\times\vec{B}\right)$ is the energy per unit time, transported by the electromagnetic fields.
   [c] The Poynting vector is parallel to both electric field $\vec{E}$ and magnetic field $\vec{B}$.
   [d] The modified form of Ampere's Law is $\nabla\times\vec{B} = \mu_0\vec{J} + \varepsilon_0\frac{\partial\vec{E}}{\partial t}$.

10. A superconductor is a material in which (below the maximum superconducting temperature)
   [a] $R = 0$, the magnetic field $B = 0$, and $\chi_{\text{magnetic}} = 0$.
   [b] $R = 0$, the magnetic field $B = \infty$, and $\chi_{\text{magnetic}} = 0$.
   [c] $R = 0$, the magnetic field $B = 0$, and $\chi_{\text{magnetic}} < 0$.
   [d] $R = 0$, the magnetic field $B = 0$, and $\chi_{\text{magnetic}} > 0$.

Fill the following blanks with appropriate answers.

11. The Laplacian of the function $\vec{F} = \ln(y)\hat{i} + z^2\hat{j} - \sin(2\pi x)\hat{k}$ at $(1,1,\pi)$ is .....

12. The electric field in a region of space is given by $E_x = (3.0x)$ N/C, $E_y = E_z = 0$, where x is in m. Points A and B are on the x axis at $x_A = 3.0$ m and $x_B = 5.0$ m. The potential difference $V_B - V_A$ (in volt) is equal to .....

13. Domain formation is the necessary feature of .....

14. The direction of induced emf is given by .....

15. In the decay ${}^{234}_{90}\text{Th} \rightarrow {}^{A}_{Z}\text{Ra} + {}^{4}_{2}\text{He}$, the mass number and the atomic number of the Ra nucleus are ..... , ...

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F.M. : 40

SECTION "B"
[5Q × 3 = 15 marks]

1. Calculate the divergence and the curl of the vector function $\vec{A} = y^2\hat{i} + \left(2xy + z^2\right)\hat{j} - 2xz\hat{k}$.

2. Derive an expression for potential energy of the configuration of three charges (Figure B-1) and generalize the result for a system of n point charges.

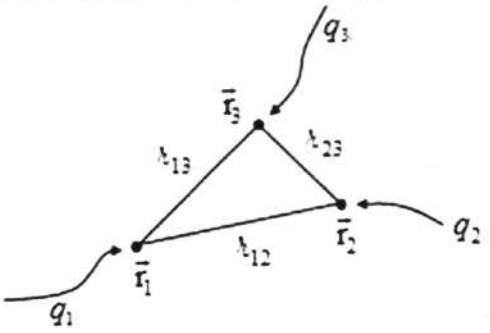

Figure B-1

OR

Find the energy of a uniformly charged spherical shell of total charge q and radius R.

3. Show that a current loop with area A and current I in a uniform magnetic field $\vec{B}$ experiences no net magnetic force, but does experience a magnetic torque $\vec{N} = \left(I\,\vec{A}\right) \times \vec{B}$.

4. Find the magnetic field at point P on the axis of a tightly wound solenoid (helical coil) consisting of n turns per unit length wrapped around a cylindrical tube of radius 'a' and carrying current I (Figure B-2) Express your answer in terms of θ_1 and θ_2. Consider the turns to be essentially circular. What is the field on the axis of an infinite solenoid (infinite in both directions)?

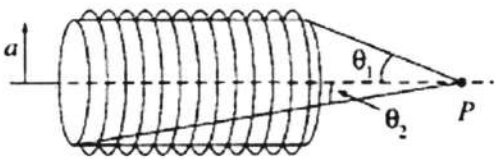

Figure B-2

OR

Find the vector potential of an infinite solenoid with n turns per unit length, radius R, and current I.

5. Define half-life of a radioactive substance and show that $T_{\frac{1}{2}} = \dfrac{(\ln 2)\Delta t}{\ln\left(\dfrac{R_0}{R}\right)}$, where Δt is the time interval during which the decay rate decreases form R_0 to R.

OR

When the nuclear reaction represented by Equation $a + X \rightarrow Y + b$ is endothermic, the reaction energy Q is negative. For the reaction to proceed, the incoming particle must have a minimum energy called the threshold energy. Show that $E_{th} = Q\left(1 + \dfrac{M_a}{M_X}\right)$.

SECTION "C"

[5Q × 5 = 25 marks]

6. A (physical) **electric dipole** consists of two equal and opposite charges ($\pm q$) separated by a distance d. Find the approximate potential at points far from the dipole. Show that the electric field of a dipole in spherical polar coordinate system is given by

$$\vec{E}_{dip}(r, \theta) = \frac{p}{4\pi\varepsilon_0 r^3}(2\cos\theta\ \hat{r} + \sin\theta\ \hat{\theta}).$$

7. How did Maxwell fix Ampere's law? Explain. Write down Maxwell's equations in regions of space where there is no charge or current and derive the wave equation for electric field $\vec{E}$ and magnetic field $\vec{B}$ for electromagnetic waves in a vacuum.

OR

State and prove "work-energy theorem" of electrodynamics.

8. Define mutual inductance. Derive the Neumann formula for mutual inductance of the two loops and hence give the statement of reciprocity theorem.

9. Explain the Raman Effect with schematic diagram of experimental setup. Give the quantum mechanical explanation of Raman spectra with energy level diagram.

OR

What are superconductors? Explain the Meissner effect and critical magnetic field in superconductors.

10. A thin rod of length $2L$ and uniform charge per unit length λ lies along the y-axis as shown in Figure C-1. Show that the electric field at P, a distance z above the midpoint of the rod is given by $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\lambda\sin\theta}{z}\hat{k}$. Also, show that the electric field of a rod of infinite length is $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{z}\hat{k}$.

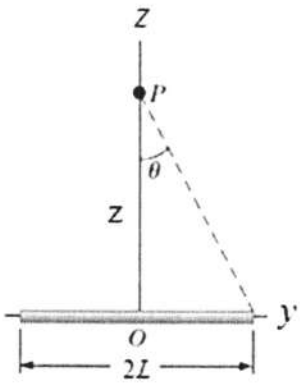

Figure C-1

OR

A disk of radius R has a uniform surface charge density σ. Calculate the electric field a point P that lies along the central perpendicular axis of the disk and a distance z from the centre of the disk (Figure C-2). What does your formula give in the limit $R \to \infty$? Also, check the case $z \gg R$.

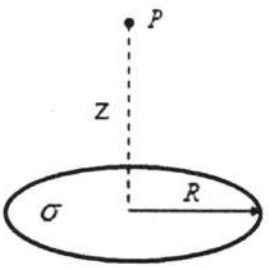

Figure C-2