Yashwantrao Chavan College of Science Karad

B.Sc. Part-III Semester-V PHYSICS Paper-IX

DSE-E1 Mathematical Physics and Classical Electrodynamics

Question Bank

Unit I: Orthogonal Curvilinear Co-ordinates:

Long Answer Question

1. Obtain the unit vectors in the Spherical polar coordinate system.
2. Derive the expression for the volume element in the general curvilinear coordinates
3. Explain the Cartesian, Spherical Polar, and cylindrical coordinate systems.
4. What are unit tangent vectors? Derive the expressions for unit tangent vectors in Cartesian, Spherical Polar, and cylindrical coordinate systems.
5. Derive the expressions for arc length, area, and volume elements in an orthogonal curvilinear coordinate system.
6. Define the gradient of a scalar field in an orthogonal curvilinear coordinate system. Derive the gradient in Cartesian, Spherical Polar, and cylindrical coordinate systems.
7. What is the divergence of a vector field? Derive the general expression for divergence in an orthogonal curvilinear coordinate system.
8. Define the curl of a vector field. Derive the expression for curl in an orthogonal curvilinear coordinate system.
9. Explain the Del operator and its significance in vector calculus. Derive the expression for the Laplacian in orthogonal curvilinear coordinate systems, and extend it to Cartesian, Spherical Polar, and cylindrical coordinates.
10. Compare and contrast the Cartesian, Spherical Polar, and cylindrical coordinate systems.

Short Answer Question

1. Convert the Cartesian point (x, y, z) to cylindrical coordinates.
2. How do orthogonal curvilinear coordinates differ from Cartesian coordinates?
3. How do the area and volume elements change when switching from Cartesian to curvilinear coordinates?
4. What is the formula for the volume element in Spherical Polar coordinates?
5. What is the role of scale factors in computing the gradient in curvilinear coordinates?
6. What is the expression for divergence in cylindrical coordinates? Describe the physical meaning of divergence.
7. Explain the curl in Spherical Polar coordinates. What does a zero curl indicate about a vector field?
8. Explain the Laplacian in Spherical Polar coordinates.
9. How is the curl operator extended from Cartesian to cylindrical coordinates?
10. What is the significance of the Laplacian in Spherical Polar coordinates?

Unit II: Partial Differential Equation

Long Answer Question

1. Discuss the differences between ordinary and partial differential equations, and provide examples of physical phenomena that can be modeled using differential equations.
2. Describe the method of separation of variables for solving second-order partial differential equations
3. Consider the one-dimensional wave equation $\partial^2 u / \partial t^2 = c^2 \partial^2 u / \partial x^2$, where c is the speed of the wave. Solve this equation to obtain the general solution $u(x,t)=f(x-ct)+g(x+ct)u(x,t) = f(x-ct) + g(x+ct)u(x,t)=f(x-ct)+g(x+ct)$, and explain the physical meaning of this solution, representing a wave traveling in the positive and negative directions.
4. Derive the two-dimensional Laplace differential equation in Cartesian coordinates.
5. Write down the differential equation of a progressive wave. Discuss the physical interpretation of this equation and provide a detailed solution.

Short Answer Question

1. Solve the three-dimensional Laplace equation $\partial^2 u / \partial x^2 + \partial^2 u / \partial y^2 + \partial^2 u / \partial z^2 = 0$ within a cube of side L with zero boundary conditions on all faces.
2. Solve the differential equation for the motion of a simple harmonic oscillator given by $d^2x/dt^2 + \omega^2 x = 0$ and discuss the physical interpretation of the solution.

Unit III: Charge Particle Dynamics

Q.1 Derive passions and Laplace equation and discuss their significance

Q.2 Discuss the nature of trajectory of a charged particle entering in uniform electric field, such that initial initial velocity is perpendicular to the electric field.

Q. 3 Show that charge particle moves along circular path with a constant speed, in a uniform magnetic field.

Q.4 Show that charge particle moves along cycloid, when it enters mutually perpendicular electric and magnetic field and the constant drift velocity is independent of charge and mass of the particle.

Q.5 Calculate the radius of circular orbit of an electron of kinetic energy 5 keV in the field of 10^{-4} T.

Unit IV: Maxwell's Equation

Q.1 State Maxwell's equation for vacuum and derive equations giving divergence and curl of electric field.

Q.2 State Maxwell's equation for vacuum and derive equations giving divergence and curl of magnetic field.

Q.3 State Maxwell's equation for material medium and derive equations giving divergence and curl of electric field.

Q.4 State Maxwell's equation for material medium and derive equations giving divergence and curl of magnetic field.

Q.5 Write a note on electric displacement current.

Q.6 Explain physical significance of Maxwell's equation.

Q.7 State and explain Biot Savart's Law and hence show that $\nabla . \vec{B} = 0$

Q.8 State and prove Ampere's circuital law.

Q.9 Show that differential forms of Ampere's circuital law for steady current is $\nabla \times \vec{B} = \mu_0 J$.

Q.10 Explain Maxwell's correction for Ampere's circuital law. Why correction was needed.