AP PHYSICS C: ELECTRICITY AND MAGNETISM • EXERCISE SHEET

8.4 Electric Fields of Charge Distributions

Name: ____________ Class: ________ Date: __________ **Total: 8 marks**

KEY WORDS linear charge density 线电荷密度 • volume charge density 体电荷密度 • surface charge density 面电荷密度 • symmetry 对称性 • continuous charge distribution 连续电荷分布

Objective

Build the skills to answer exam questions on **electric fields of charge distributions**.

You must be able to:

- treat a **continuous charge distribution** 连续电荷分布 as many elements dq
- relate dq to **linear**, **surface**, and **volume charge density** (λ, σ, ρ)
- set up an **integral** for the field of a symmetric distribution
- use **symmetry** 对称性 to see which field components cancel

1 Worked examples

Study these first. Each one shows the method for a question type used later.

From point charge to integral

Split the charge into elements dq, each giving $dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}$, then $\vec{E} = \int d\vec{E}$.

Charge densities

$\lambda = \frac{dq}{dl}$ (per length), $\sigma = \frac{dq}{dA}$ (per area), $\rho = \frac{dq}{dV}$ (per volume).

Symmetry and the far field

By symmetry, components perpendicular to the axis cancel; only the axial part survives. Far away, any finite distribution looks like a **point charge** ($E \to kQ/r^2$).

2 Practice

2.1 Write the charge dq on a length dl of a rod with linear charge density λ. [1]

2.2 State the SI units of surface charge density σ. [1]

2.3 State what the field of any finite charge distribution looks like from very far away. [1]

3 Exam-style questions

3.1 The linear charge density λ is defined as [1]

- **A** charge per unit volume
- **B** charge per unit area
- **C** charge per unit length
- **D** charge $\times$ length

3.2 To find the field of a continuous distribution you [1]

- **A** add two point charges
- **B** integrate $d\vec{E}$ over all the charge elements dq
- **C** use $V = IR$
- **D** ignore symmetry

3.3 A ring of radius a carries total charge Q. On its axis at distance x the field is $E = \frac{kQx}{(x^2+a^2)^{3/2}}$.

(a) State the field at the centre of the ring ($x = 0$). [1]

(b) State what E approaches when $x \gg a$, and explain. [2]

Solutions

2.1 $dq = \lambda\, dl$.

2.2 C m^{-2}.

2.3 it approaches the field of a point charge.

3.1 **C**.

3.2 **B**.

3.3 (a) $E = 0$ (the contributions cancel by symmetry). (b) $E \to \dfrac{kQ}{x^2}$ — far away the ring looks like a point charge Q.