2.1 Electromagnetism

Name: _____ Class: _____ Date: _____ **Total: 12 marks**

KEY WORDS flux • potential

Objective

Use electrostatic potentials, fields and Gauss's law; Analyse circuits, magnetism and induction; Apply Maxwell equations and electromagnetic wave relationships. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

Electric field is the negative gradient of potential . A value and a spatial change are different quantities.

Use Gauss's law with symmetry. A known total flux alone does not give the field at every surface point.

Kirchhoff's laws track charge and energy in circuits. Induced emf follows changing magnetic flux with the Lenz-law sign.

Maxwell equations link electric and magnetic fields. In vacuum a wave has E/B=c and carries energy.

■ Worked method

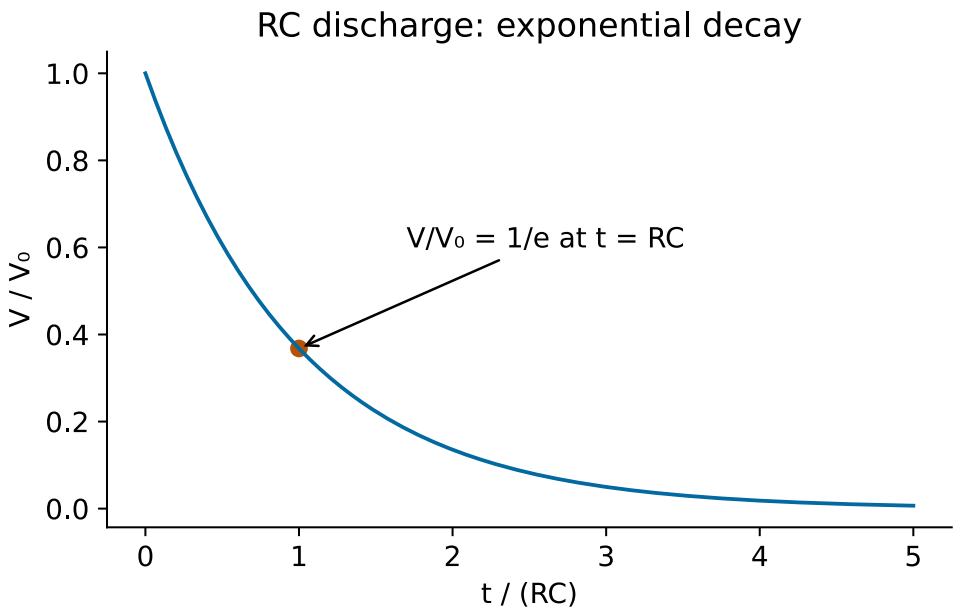
A spherical shell has radius R and uniform charge Q. Choose zero potential at infinity. Spherical symmetry lets Gauss's law determine the field outside.

$$4\pi r^2 E = Q/\epsilon_0, \qquad E = Q/(4\pi\epsilon_0 r^2) \quad (r > R).$$

Inside, enclosed charge is zero and symmetry gives E = 0. Continuity gives

$$V(r) = \begin{cases} Q/(4\pi\epsilon_0 R) & r \le R, \\ Q/(4\pi\epsilon_0 r) & r > R. \end{cases}$$

The potential is nonzero and constant inside. A zero gradient, rather than a zero value, gives a zero field. The radial field jumps at the charged surface.



2 Practice

2.1 Choose one answer. An RC time constant has units of: [1]

- **A** seconds
- **B** volts
- **C** amperes

2.2 Choose one answer. For an ideal electrostatic conductor in equilibrium, its internal electric field is: [1]

- **A** zero
- **B** always positive
- **C** infinite

2.3 For R=1000 ohms and C=0.002 farads, RC=_____ seconds. Show your relation and units. [2]

2.4 Decide whether this claim is true. Justify it: A constant nonzero potential must mean a nonzero electric field. [2]

3 Exam-style questions

3.1 Two concentric thin spherical shells have radii R and 2R, and charges Q and -Q. Derive E and V in all three radial regions, with zero potential at infinity. Check continuity of V at both shells. [6]

Solutions

2.1 A Resistance times capacitance has units of time.

Compare the rejected options: volts; amperes. Use the stated model and conditions.

2.2 A Free charges rearrange until the internal electrostatic field vanishes.

Compare the rejected options: always positive; infinite. Use the stated model and conditions.

2.3 2. Multiply $1000\times0.002=2$.

2.4 False. The field depends on the gradient, which is zero for constant potential.

3.1 Let $k = 1/(4\pi\epsilon_0)$ and positive field mean radially outward. For $r < R$, $E = 0$ and $V = kQ/R - kQ/(2R) = kQ/(2R)$. For $R < r < 2R$, $E = kQ/r^2$ and $V = kQ/r - kQ/(2R)$. For $r > 2R$, both E and V are zero. At R the two potentials give $kQ/(2R)$; at 2R they give zero. Normal E jumps at the surface charges. Award each region's pair one mark, each continuity check one, and field-jump interpretation one.