Suggested solutions to exam in Applied Electromagnetism 071025

1

In the series case

$$C_{tot} = \left(\frac{1}{C}+\frac{1}{C}+\frac{1}{C}\right)^{-1} = \frac{C}{3} \Rightarrow W_{tot,series} = \frac{C_{tot}U^2}{2} = \frac{1}{3}\frac{CU^2}{2}$$

And in the parallel case:

$$C_{tot} = 3C \Rightarrow W_{tot,par} = \frac{C_{tot}U^2}{2} = 3\frac{CU^2}{2}$$

The energy in the parallel case is nine times the energy in the series case.
If you look at the problem with field energy instead:
E-field has the same volume in both cases but is three times lager in the parallel case. As energy in proportional to E², this means the energy is nine times higher.

2

Let a = 10mm

$$\vec{E} = \frac{2\lambda}{2\pi\varepsilon_0\sqrt{a^2+x^2}}(\cos\theta,0,0) \Rightarrow E_x = \frac{2\lambda x}{2\pi\varepsilon_0\left(x^2+a^2\right)}$$

We look for the max of this:

$$\frac{dE_x}{dx} = \frac{\lambda}{2\pi\varepsilon_0}\left(\frac{1}{x^2+a^2} - \frac{x\cdot 2x}{\left(x^2+a^2\right)^2}\right) = \frac{\lambda}{2\pi\varepsilon_0}\frac{a^2-x^2}{x^2+a^2} = 0 \Rightarrow x = a$$

The field is zero at x=0 and in infinity so this has to be a max

3

The field of a dipole far away (yes 0.1 µm is far away compared to the molecule size around 0,001 µm) is

$E_{along} = \frac{p}{2\pi\varepsilon_0 r^3} = 108\ \mathrm{V/m}$ increasing the outer field

$E_{perpendicular} = \frac{p}{4\pi\varepsilon_0 r^3} = 54\ \mathrm{V/m}$ decreasing the outer field

4

The resistance of a thin slice with thickness dz is

$$dR = \frac{\rho}{\pi r^2}dz = \frac{a\rho}{\pi b^2\left(a+|z|\right)}dz \Rightarrow R = \frac{2a\rho}{\pi b^2}\int_0^{1,5mm}\frac{1}{a+z}dz = \frac{2a\rho}{\pi b^2}\left[\ln\left(\frac{3,5}{2}\right)\right] = 1.07\ \Omega$$

a= 2 mm and b = 0.3 mm.
Yielding a voltage 1.28 V

5-6

There are a lot of assumptions and approximations you have to do for yourself in this task
First typical speed of the electrons: 5kV gives a kinetic energy if 8×10^{-16} J, giving a velocity of 4×10^7 m/s. Now look at an electron travelling towards the center of the screen (does not have to be deflected by the internal magnets) its path gets a radius of curvature of around 5 m because of the earths B-field (0.00004 T). This gives deflected angle on a 0,5m long path of 5.7°, giving a displacement of around 2 cm. You probably have to adjust horizontal position of your TV set if you rotate it 180° if it is not done automatically (it is mostly). But remember this calculation is very coarse!