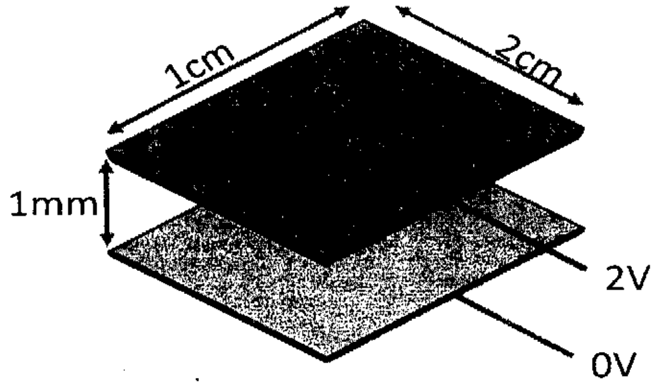
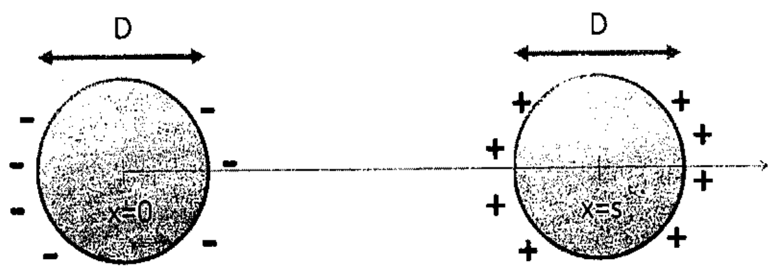
1. Consider the structure of two parallel metal plates separated by an air gap as shown below.



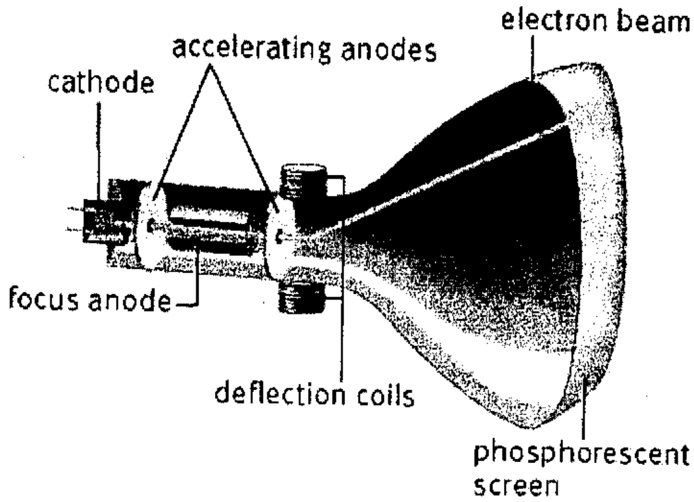
(a) Calculate the electric field under the applied voltage in the middle of the structure. (4%)
(b) How does the capacitance of the structure change if the distance is doubled? (4%)
(c) Find 3 ways to increase the capacitance of the structure. (4%)
(d) What is the unit of the permittivity ε ? (4%)
(e) How many elemental charges ($e = 1.602\times10^{-19} As$) are stored on the top plate? (Hint: $\frac{\varepsilon_0}{e} = 5.5\times10^{7}[unit]$) (4%)

2. The picture below shows two conductive empty, spherical shells. (All charges are located only on their surface.)



(a) How does the force between the two spheres change when s is doubled? (5%)
(b) Explain how and why the force between the two spheres changes when they are immersed in water. (Assume that the charges remain on the spheres). (4%)
(c) Plot the magnitude of the electric field (plot as y axis) along the line indicated in the picture between x=0 and x=s, (Please label the position of D/2 and s-D/2 in the axis of your plot). (4%)

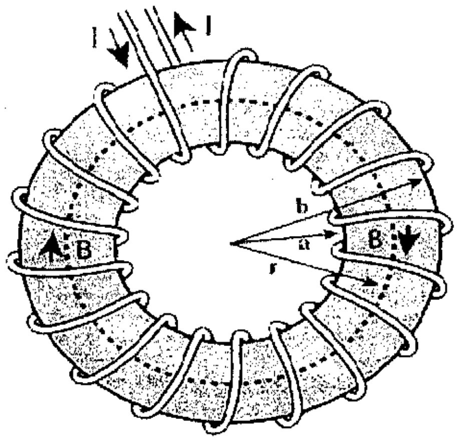
3. In a cathode ray tube TV an electron is accelerated from rest through a potential difference of 9900V.



(a) What is the final electron speed ? (hint: $e/me=1.75\times10^{11}$C/kg) (5%)
(b) The accelerated electron then flies into a magnetic field of 1T perpendicular to the electron path. What is the new final speed? (4%)
(c) If every electron hitting the phosphorescent screen would generate only one green photon (wavelength λ=532nm), what would be the efficiency of the TV? (4%)
(d) Our electron beam has a current of 1nA and we require 10 electrons to hit each pixel on the phosphorescent screen. How fast can a picture of 1920x1200 Pixel HDMI resolution be displayed? What refresh frequency does that correspond to? (4%)

4. The magnetic field equations for an electromagnetic wave in free space are $B_x = B\sin(ky+\omega t)$, $B_y = B_z = 0$,
(a) What is the direction of propagation? (2%)
(b) Write the electric field equations (3%)
(c) Is the wave polarized? If so, in what direction? (2%)
(d) Find the instantaneous Poynting vector. (3%)

5. A toroidal coil consists of a circular ring, or "donut", around which a long wire is wrapped. The winding is uniform and tight enough so that each turn can be considered a closed loop. The coil has rectangular cross section (inner radius a, outer radius b, height h), current I, and carries a total n turns (see figure in below).
   (a) Find the magnetic field $\vec{B}$ at all points, both inside and outside the coil. You must show both direction of the field and the magnitude. (10%)
   (b) Find the flux through a single turn. (5%)
   (c) Find the self-inductance of the toroidal coil. (5%)



6. An alternating current $I = I_0 \sin(\omega t)$ flows down a long straight wire and back along a coaxial conducting cylinder of radius R (see figure in below).
   (a) In what direction does the induced electric field point (radial, circumferential, or longitudinal)? (3%)
   (b) Find $\vec{E}$ as a function of r (the distance from the axis). (7%)
   (c) Find the displacement current density, $\vec{J_d}$. (5%)
   (d) Integrate it to get the total displacement current (5%)

$$I_d = \int \vec{J_d} \cdot d\vec{a}$$