Exam-02

1. Consider a parallel-plate capacitor that has a separation between the plates of d = 0.01 mm. Assume that the area of each plate is A = 0.1 m^2. The plates are split into two areas, A_1 and A_2, so that $A = A_1 + A_2$ where $A_1 = A_2$. Area A_1 is filled with air, while area A_2 is filled with a dielectric with ε_r = 5.0. A charge $Q = 10^{-5}$ C is located on the 1st plate, and $-Q = -10^{-5}$ C is located on the 2nd plate.
   (a) Draw the experimental setup and label all objects appropriately. Calculate the capacitance of the capacitor and the voltage that drops across the capacitor.
   (b) Assume that a charge Q_1 is located within the area A_1 and a charge Q_2 is located within the area A_2 so that $Q_1 + Q_2 = Q$. Determine Q_1 and Q_2.
   (c) Determine the energy stored between the plates within the area A_1; then determine the energy stored within A_2.
   (d) How does this question help us to understand the meaning of the 'relative permittivity' ε_r (also called dielectric constant, ε_r)?

2. This question concerns a capacitor with *three* parallel plates. The center plate has the charge Q and two outer plates have the charge $-\frac{1}{2}Q$. The two outer plates, separated from the center plate by distance d, are electrically connected to each other (electrically shorted). All plates have the area A. Fringe fields can be neglected.
   (a) Draw the experimental setup and label all objects appropriately. Calculate the electric field between plates (symbolic expression).
   (b) Calculate the voltage between plates. Calculate the capacitance.
   (c) Discuss the advantages or disadvantages of this three-parallel-plate capacitor compared with a conventional two-parallel-plate capacitor.

3. Coulombic interaction is the interaction of electrical charges. Consider two negative charges in air that are initially separated, then brought into closer contact, until they are co-located (fully overlap).
   (a) Draw the experimental setup. Describe in your own words the changes in electric field that occur during the above-described process. Describe the changes in energy density of the electric field.
   (b) Explain in your own words, *why* two negative charges repel each other, or, more generally, why like charges (– – and + +) repel each other.
   (c) Red blood-cells in the human blood stream must not stick to each other (must not form a blood-clot). If you were to design red blood-cells, can you propose a method that would prevent red blood-cells from sticking to each other?

4. Determine if the following statements are (i) true, (ii) false, or (iii) impossible to determine due to lack of information. Explain each of your answers with a few words.
   (a) An open convertible car can serve as a Faraday cage and thus protect from lightning.
   (b) A grounded metal sphere must be charge-neutral and not carry a positive or negative charge.
   (c) 6.242×10^{18} electrons have the total charge of about –1.0 C.
   (d) The relative permittivity ε_r of any solid material is generally greater than 1.0.