# High Level Problems (HLP)

✍ **Marked Questions can be used as Revision Questions.**

## SUBJECTIVE QUESTIONS

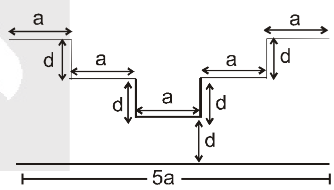
**1.** A capacitor having a capacitance of 200 μF is charged to a potential difference of 20V. The charging battery is disconnected and the capacitor is connected to another battery of emf 10V with the positive plate of the capacitor joined with the positive terminal of the battery.
(a) Find the charges on the capacitor before and after the reconnection in steady state.
(b) Find the net charge flown through the 10 V battery
(c) Is work done by the battery or is it done on the battery? Find its magnitude.
(d) Find the decrease in electrostatic field energy.
(e) Find the heat developed during the flow of charge after reconnection.

**2.** Six 1 μF capacitors are so arranged that their equivalent capacitance is 0.70 μF. If a potential difference of 600 volt is applied to the combination, what charge will appear on each capacitor?

**3.** A battery of 10 volt is connected to a capacitor of capacity 0.1 F. The battery is now removed and this capacitor is connected to a second uncharged capacitor. If the charge distributes equally on these two capacitors, find the total energy stored in the two capacitors. Further, compare this energy with the initial energy stored in the first capacitor. **[REE - 1996,5]**

**4.** The circular plates A and B of a parallel plate air capacitor have a diameter of 0.1 m and are 2 x $10^{-3}$ m apart. The plates C and D of a similar capacitor have a diameter of 0.12 m and are 3 x $10^{-3}$ m apart. Plate A is earthed. Plates B and D are connected together. Plate C is connected to the positive pole of a 120 volt battery whose negative is earthed. Calculate **[REE - 1998,5]**
(i) The combined capacitance of the arrangement and
(ii) The energy stored in it.

**5.** A capacitor is made of a flat plate of area A and a second plate having a stair-like structure as shown in figure. The width of each stair is a and the height is d. Both plates have the same width perpendicular to plane of paper. Find the capacitance of the assembly.

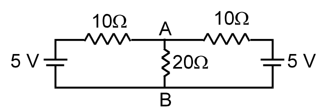



**6.**✍ Calculate the capacitance of a parallel plate condenser, with plate area A and distance between plates d, when filled with a dielectric whose dielectric constant varies as; **[REE 2000,6]**

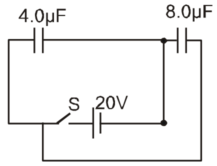
$$K(x) = 1 + \frac{\beta x}{\epsilon_0} \quad 0 < x < \frac{d}{2}\ ; \qquad K(x) = 1 + \frac{\beta}{\epsilon_0}(d - x) \quad \frac{d}{2} < x < d.$$

For what value of β would the capacity of the condenser be twice that when it is without any dielectric?

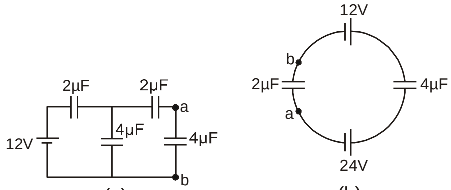
**7.** (a) Find the current in the 20 Ω resistor shown in figure.
(b) If a capacitor of capacitance 4μF is joined between the points A and B, what would be the electrostatic energy stored in it in steady state ?



**8.** (i) Find the total charge flown through the battery in the arrangement shown in figure after switch S is closed (initially all the capacitors are uncharged).
(ii) Find out final charge on each capacitor.

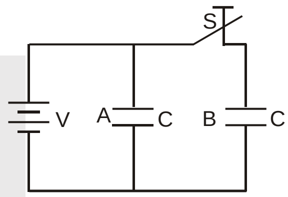



**9.** Find the potential difference $V_a - V_b$ between the points a and b shown in each part of the figure.

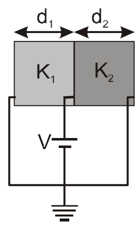


(a) (b)

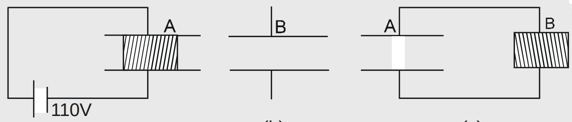
**10.** The figure shows two identical parallel plate capacitors connected to a battery with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant (or relative permittivity) 3. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric. **[JEE 1983; 6M]**




**11.** A capacitor is composed of three parallel conducting plates. All three plates are of the same area A. The first pair of plates are kept a distance $d_1$ apart, and the space between them is filled with a medium of a dielectric $K_1$ . The corresponding data for the second pair are $d_2$ and $K_2$ , respectively.
The middle plate is connected to the positive terminal of a constant voltage source V and the external plates are connected the other terminal of V.
(a) Find the capacitance of the system.
(b) What is the surface charge density on the middle plate ?
(c) Compute the energy density in the medium $K_1$ .




**12.** Two parallel plate capacitors A and B have the same separation d = 8.85 x $10^{-4}$ m between the plates. The plate areas of A and B are 0.04 $m^2$ and 0.02 $m^2$ respectively. A slab of dielectric constant (relative permittivity K = 9) has dimensions such that it can exactly fill the space between the plates of capacitor B. **[JEE 1993, 2+3+2=7 Marks]**



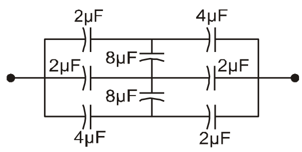
(a) (b) (c)

(i) The dielectric slab is placed inside A as shown in the figure (a). A is charged to potential difference of 110 V. Calculate the capacitance of A and energy stored in it :

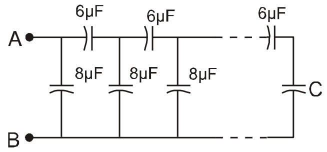
(ii) The battery is disconnected and then the dielectric also slab is moved from A. Find the work done by the external agency in removing the slab from A.

(iii) The same dielectric slab is now placed inside B, filling it completely. The two capacitors A and B are then connected as shown in the figure (c) . Calculate the energy stored in the system.

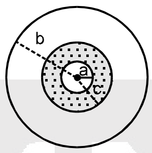
**13.** Find the equivalent capacitance of the combinations shown in the figure between the indicated points.



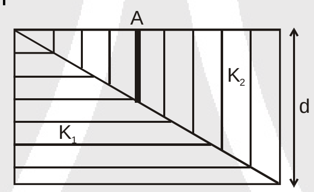
**14.** A finite ladder circuit is constructed by connecting several sections of 6 μF, 8 μF capacitor combinations as shown in the figure. Circuit is terminated by a capacitor of capacitance C. Find the value of C, such that the equivalent capacitance of the ladder between the points A and B becomes independent of the number of sections in between?




**15.** A spherical capacitor is made of two conducting spherical shells of radii a and b = 3a. The space between the shells is filled with a dielectric of dielectric constant K = 3 upto a radius c = 2a as shown. If the capacitance of given arrangement is n times the capacitance of an isolated spherical conducting shell of radius a. Then find value of n.




**16.** The capacitance of a parallel plate capacitor with plate area A and separation d, is C. The space between the plates is filled with two wedges of dielectric constant $K_1$ and $K_2$ respectively (figure). Find the capacitance of the resulting capacitor. **[JEE-1996; 2M/100]**




## HLP Answers

**1.** (a) 4000 μC, 2000 μC (b) 2000 μC (c) work is done on the battery, 20 mJ (d) 30 mJ (e) 10 mJ

**2.** 420 μC on one, 180 μC on two, 60 μC on remaining 3 capacitors

**3.** $\frac{5}{2}$ J, $\frac{U_{initial}}{U_{final}} = \frac{5}{2.5} = 2$

**4.** (i) $\frac{30\pi \in_0}{49} \approx 17$pF (ii) 122.4 nJ

**5.** $\frac{8 \in_0 A}{15 \; d}$

**6.** $C = \frac{A\beta}{2\ell n\left(1+\frac{\beta d}{2 \in_0}\right)}$ , $\beta d = 4\in_0 \ell n\left(1+\frac{\beta d}{2 \in_0}\right)$ Solution of this equation gives required value of β .

**7.** (a) $\frac{1}{5}$ A (b) 32 μJ

**8.** (i) 240 μC (ii) $Q_{4\mu F}$ = 80 μC, $Q_{8\mu F}$ = 160 μC

**9.** (a) $\frac{12}{11}$ V (b) – 8 V

**10.** $\frac{3}{5}$

**11.** (a) $\in_0 A\left(\frac{K_1}{d_1}+\frac{K_2}{d_2}\right)$ (b) $\frac{Q_1}{A} = \left(\frac{K_1 \in_0 A}{d_1}\right)\frac{V}{A} = \frac{K_1 \in_0}{d_1}V$ and $\frac{Q_2}{A} = \left(\frac{K_2 \in_0 A}{d_2}\right)\frac{V}{A} = \frac{K_2 \in_0}{d_2}V$ (c) $\frac{\in_0 K_1 V^2}{2d_1^2}$

**12.** (i) 2nF, 12.1μJ (ii) 48.4μJ (iii) 11μJ

**13.** $\frac{27}{7}$ μF

**14.** 12 μF

**15.** n = 3

**16.** $C_R = \frac{CK_1K_2}{K_2 - K_1} \ln \frac{K_2}{K_1}$ where $C = \frac{\in_0 A}{d}$