fo/u fopkjr Hkh# tu] ugh vkjEHk dke] foifr n[k NkM rjr e/;e eu dj ';keA
i#"k flg ldYi dj] lgr foifr vud] ^cuk^ u NkM /;; dk] j?kcj jk[k VdAA

jfpr% ekuo /ke i.krk
lnx# Jh j.kNkMnklth egkjkt

STUDY PACKAGE

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Topic : CAPACITANCE

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SHORT REVESION

1. CAPACITANCE OF AN ISOLATED SPHERICAL CONDUCTOR :

$C = 4\pi \in_0 \in_r R$ in a medium $\qquad C = 4\pi \in_0 R$ in air

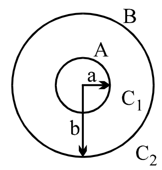
* This sphere is at infinite distance from all the conductors .

* The capacitance $C = 4\pi \in_0 R$ exists between the surface of the sphere & earth .

2. SPHERICAL CAPACITOR :

It consists of two concentric spherical shells as shown in figure. Here capacitance of region between the two shells is C_1 and that outside the shell is C_2. We have

$$C_1 = \frac{4\pi \in_0 ab}{b - a} \qquad \text{and} \quad C_2 = 4\pi \in_0 b$$



Depending on connection, it may have different combinations of C_1 and C_2.

3. PARALLEL PLATE CAPACITOR :

(i) UNIFORM DI-ELECTRIC MEDIUM :

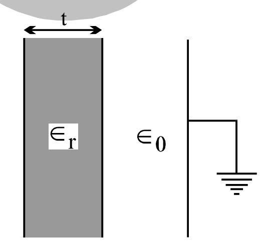
If two parallel plates each of area A & separated by a distance d are charged with equal & opposite charge Q, then the system is called a parallel plate capacitor & its capacitance is given by,

$$C = \frac{\in_0 \in_r A}{d} \text{ in a medium} \quad ; \quad C = \frac{\in_0 A}{d} \text{ with air as medium}$$

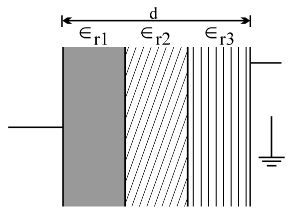
This result is only valid when the electric field between plates of capacitor is constant.

(ii) MEDIUM PARTLY AIR : $\quad C = \dfrac{\in_0 A}{d - \left(t - \frac{t}{\in_r}\right)}$

When a di-electric slab of thickness t & relative permittivity $\in_r$ is introduced between the plates of an air capacitor, then the distance between the plates is effectively reduced by $\left(t - \dfrac{t}{\in_r}\right)$ irrespective of the position of the di-electric slab .

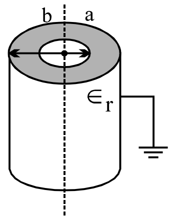


(iii) COMPOSITE MEDIUM : $\quad C = \dfrac{\in_0 A}{\frac{t_1}{\in_{r1}} + \frac{t_2}{\in_{r2}} + \frac{t_3}{\in_{r3}}}$



4. CYLINDRICAL CAPACITOR :

It consist of two co-axial cylinders of radii a & b, the outer conductor is earthed . The di-electric constant of the medium filled in the space between the cylinder is $\in_r$. The capacitance per unit length is $C = \dfrac{2\pi \in_0 \in_r}{\ell n\left(\frac{b}{a}\right)} \dfrac{\text{Farad}}{\text{m}}$.



5. CONCEPT OF VARIATION OF PARAMETERS:

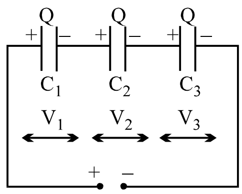
As capacitance of a parallel plate capacitor is $C = \dfrac{\epsilon_0 kA}{d}$, if either of k, A or d varies in the region between the plates, we choose a small dc in between the plates and for total capacitance of system.

If all dC's are in series $\dfrac{1}{C_T} = \int \dfrac{dx}{\epsilon_0 k(x) A(x)}$, If all dC's are in parallel $C_T = \int dC$

6. COMBINATION OF CAPACITORS :

(i) CAPACITORS IN SERIES :

In this arrangement all the capacitors when uncharged get the same charge Q but the potential difference across each will differ (if the capacitance are unequal).

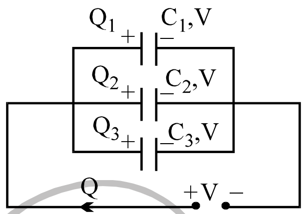


$$\frac{1}{C_{eq.}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots\dots + \frac{1}{C_n}.$$

(ii) CAPACITORS IN PARALLEL :

When one plate of each capacitor is connected to the positive terminal of the battery & the other plate of each capacitor is connected to the negative terminals of the battery, then the capacitors are said to be in parallel connection.

The capacitors have the same potential difference, V but the charge on each one is different (if the capacitors are unequal).



$C_{eq.} = C_1 + C_2 + C_3 + \dots\dots + C_n$.

7. ENERGY STORED IN A CHARGED CAPACITOR :

Capacitance C, charge Q & potential difference V; then energy stored is

$U = \dfrac{1}{2} CV^2 = \dfrac{1}{2} QV = \dfrac{1}{2}\dfrac{Q^2}{C}$. This energy is stored in the electrostatic field set up in the di-electric medium between the conducting plates of the capacitor.

8. HEAT PRODUCED IN SWITCHING IN CAPACITIVE CIRCUIT

Due to charge flow always some amount of heat is produced when a switch is closed in a circuit which can be obtained by energy conservation as –

Heat = Work done by battery – Energy absorbed by capacitor.

9. SHARING OF CHARGES :

When two charged conductors of capacitance C_1 & C_2 at potential V_1 & V_2 respectively are connected by a conducting wire, the charge flows from higher potential conductor to lower potential conductor, until the potential of the two condensers becomes equal. The common potential (V) after sharing of charges;

$$V = \frac{\text{net charge}}{\text{net capacitance}} = \frac{q_1 + q_2}{C_1 + C_2} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}.$$

charges after sharing $q_1 = C_1V$ & $q_2 = C_2V$. In this process energy is lost in the connecting wire as heat. This loss of energy is $U_{initial} - U_{real} = \dfrac{C_1 C_2}{2(C_1 + C_2)}(V_1 - V_2)^2$.

10. REMEMBER :

(i) The energy of a charged conductor resides outside the conductor in its EF, where as in a condenser it is stored within the condenser in its EF.

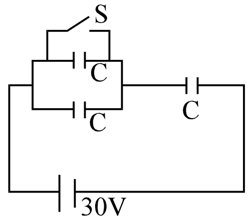
(ii) The energy of an uncharged condenser = 0 .

(iii) The capacitance of a capacitor depends only on its size & geometry & the di-electric between the conducting surface. (i.e. independent of the conductor, like, whether it is copper, silver, gold etc)

EXERCISE # I

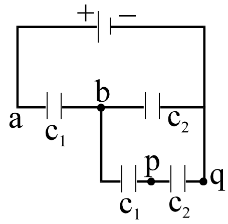
Q.1 A solid conducting sphere of radius 10 cm is enclosed by a thin metallic shell of radius 20 cm. A charge $q = 20\mu C$ is given to the inner sphere. Find the heat generated in the process, the inner sphere is connected to the shell by a conducting wire

Q.2 The capacitor each having capacitance $C = 2\mu F$ are connected with a battery of emf 30 V as shown in figure. When the switch S is closed. Find
(a) the amount of charge flown through the battery
(b) the heat generated in the circuit
(c) the energy supplied by the battery
(d) the amount of charge flown through the switch S

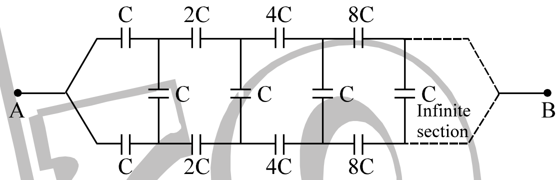


Q.3 The plates of a parallel plate capacitor are given charges +4Q and –2Q. The capacitor is then connected across an uncharged capacitor of same capacitance as first one (= C). Find the final potential difference between the plates of the first capacitor.

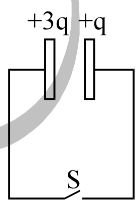
Q.4 In the given network if potential difference between p and q is 2V and $C_2 = 3C_1$. Then find the potential difference between a & b.



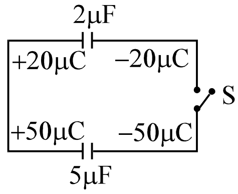
Q.5 Find the equivalent capacitance of the circuit between point A and B.



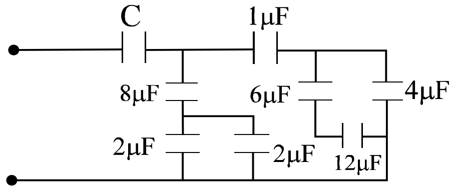
Q.6 The two identical parallel plates are given charges as shown in figure. If the plate area of either face of each plate is A and separation between plates is d, then find the amount of heat liberate after closing the switch.



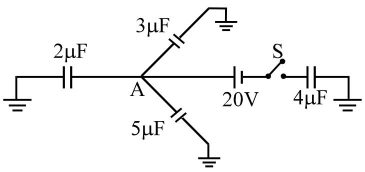
Q.7 Find heat produced in the circuit shown in figure on closing the switch S.



Q.8 In the following circuit, the resultant capacitance between A and B is 1 μF. Find the value of C.

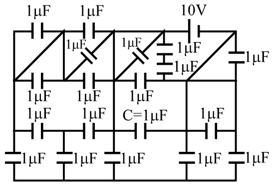


Q.9 Three capacitors of 2μF, 3μF and 5μF are independently charged with batteries of emf's 5V, 20V and 10V respectively. After disconnecting from the voltage sources. These capacitors are connected as shown in figure with their positive polarity plates are connected to A and negative polarity is earthed. Now a battery of 20V and an uncharged capacitor of 4μF capacitance are connected to the junction A as shown with a switch S. When switch is closed, find :

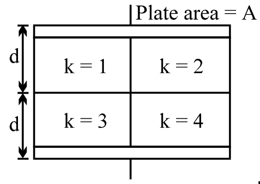


(a) the potential of the junction A.
(b) final charges on all four capacitors.

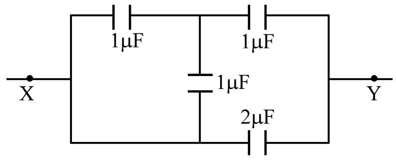
Q.10 Find the charge on the capacitor C = 1 μF in the circuit shown in the figure.



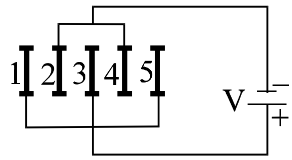
Q.11 Find the capacitance of the system shown in figure.



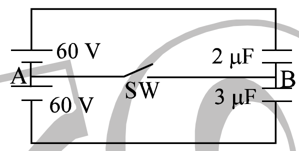
Q.12 The figure shows a circuit consisting of four capacitors. Find the effective capacitance between X and Y.



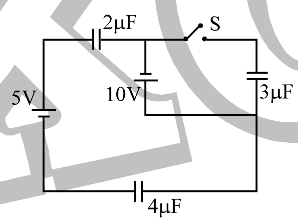
Q.13 Five identical capacitor plates, each of area A, are arranged such that adjacent plates are at a distance 'd' apart, the plates are connected to a source of emf V as shown in figure. The charge on plate 1 is_______________ and that on plate 4 is __________.



Q.14 In the circuit shown in the figure, intially SW is open. When the switch is closed, the charge passing through the switch _____________ in the direction __________ to _________ .



Q.15 In the circuit shown in figure, find the amount of heat generated when switch s is closed.



Q.16 Two parallel plate capacitors of capacitance C and 2C are connected in parallel then following steps are performed.
(i) A battery of voltage V is connected across points A and B.
(ii) A dielectric slab of relative permittivity k is slowly inserted in capacitor C.
(iii) Battery is disconnected.
(iv) Dielectric slab is slowly removed from capacitor.
Find the heat produced in (i) and work done by external agent in step (ii) & (iv).

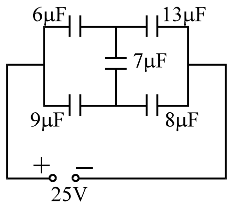
Q.17 The plates of a parallel plate capacitor are separated by a distance d = 1 cm. Two parallel sided dielectric slabs of thickness 0.7 cm and 0.3 cm fill the space between the plates. If the dielectric constants of the two slabs are 3 and 5 respectively and a potential difference of 440V is applied across the plates. Find:
(i) the electric field intensities in each of the slabs.
(ii) the ratio of electric energies stored in the first to that in the second dielectric slab.

Q.18 A 10 μF and 20 μF capacitor are connected to a 10 V cell in parallel for some time after which the capacitors are disconnected from the cell and reconnected at t = 0 with each other , in series, through wires of finite resistance. The +ve plate of the first capacitor is connected to the –ve plate of the second capacitor. Draw the graph which best describes the charge on the +ve plate of the 20 μF capacitor with increasing time.

List of recommended questions from I.E. Irodov.

3.101, 3.102, 3.103, 3.113, 3.117, 3.121, 3.122, 3.123, 3.124, 3.132, 3.133, 3.141, 3.142, 3.177, 3.184, 3.188, 3.199, 3.200, 3.201, 3.203, 3.204, 3.205

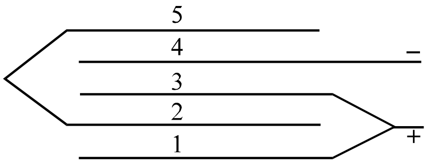
EXERCISE # II



Q.1 (a) For the given circuit. Find the potential difference across all the capacitors.
(b) How should 5 capacitors, each of capacities, 1μF be connected so as to produce a total capacitance of 3/7 μF.

Q.2 The gap between the plates of a plane capacitor is filled with an isotropic insulator whose di-electric constant varies in the direction perpendicular to the plates according to the law $K = K_1\left[1+\sin\frac{\pi}{d}X\right]$, where d is the separation, between the plates & K_1 is a constant. The area of the plates is S. Determine the capacitance of the capacitor.

Q.3 Five identical conducting plates 1, 2, 3, 4 & 5 are fixed parallel to and equdistant from each other (see figure). Plates 2 & 5 are connected by a conductor while 1 & 3 are joined by another conductor . The junction of 1 & 3 and the plate 4 are connected to a source of constant e.m.f. V_0. Find ;



(i) the effective capacity of the system between the terminals of the source.
(ii) the charges on plates 3 & 5.
Given d = distance between any 2 successive plates & A = area of either face of each plate .

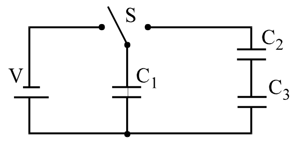
Q.4 A potential difference of 300 V is applied between the plates of a plane capacitor spaced 1 cm apart. A plane parallel glass plate with a thickness of 0.5 cm and a plane parallel paraffin plate with a thickness of 0.5 cm are placed in the space between the capacitor plates find :
(i) Intensity of electric field in each layer.
(ii) The drop of potential in each layer.
(iii) The surface charge density of the charge on capacitor the plates. Given that : $k_{glass} = 6$, $k_{paraffin} = 2$

Q.5 A charge 200μC is imparted to each of the two identical parallel plate capacitors connected in parallel. At t =0, the plates of both the capacitors are 0.1m apart. The plates of first capacitor move towards each other with relative velocity 0.001m/s and plates of second capacitor move apart with the same velocity. Find the current in the circuit at the moment.

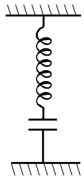
Q.6 A parallel plate capacitor has plates with area A & separation d . A battery charges the plates to a potential difference of V_0. The battery is then disconnected & a di-electric slab of constant K & thickness d is introduced. Calculate the positive work done by the system (capacitor + slab) on the man who introduces the slab.

Q.7 A capacitor of capacitance C_0 is charged to a potential V_0 and then isolated. A small capacitor C is then charged from C_0, discharged & charged again, the process being repeated n times. The potential of the large capacitor has now fallen to V. Find the capacitance of the small capacitor. If V_0 = 100 volt, V=35volt, find the value of n for C_0 = 0.2 μF & C = 0.01075 μF . Is it possible to remove charge on C_0 this way?

Q.8 When the switch S in the figure is thrown to the left, the plates of capacitors C_1 acquire a potential difference V. Initially the capacitors C_2C_3 are uncharged. Thw switch is now thrown to the right. What are the final charges q_1, q_2 & q_3 on the corresponding capacitors.



Q.9 A parallel plate capacitor with air as a dielectric is arranged horizontally. The lower plate is fixed and the other connected with a vertical spring. The area of each plate is A. In the steady position, the distance between the plates is d_0. When the capacitor is connected with an electric source with the voltage V, a new equilibrium appears, with the distance between the plates as d_1. Mass of the upper plates is m.



(i) Find the spring constant K.

(ii) What is the maximum voltage for a given K in which an equilibrium is possible ?

(iii) What is the angular frequency of the oscillating system around the equilibrium value d_1. (take amplitude of oscillation << d_1)

Q.10 An insolated conductor initially free from charge is charged by repeated contacts with a plate which after each contact has a charge Q due to some mechanism . If q is the charge on the conductor after the first operation, prove that the maximum charge which can be given to the conductor in this way is $\frac{Qq}{Q-q}$.

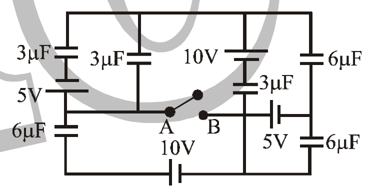
Q.11 A parallel plate capacitor is filled by a di-electric whose relative permittivity varies with the applied voltage according to the law = αV, where α = 1 per volt. The same (but containing no di-electric) capacitor charged to a voltage V = 156 volt is connected in parallel to the first "non-linear" uncharged capacitor. Determine the final voltage V_f across the capacitors.

Q.12 A capacitor consists of two air spaced concentric cylinders. The outer of radius b is fixed, and the inner is of radius a. If breakdown of air occurs at field strengths greater than E_b, show that the inner cylinder should have

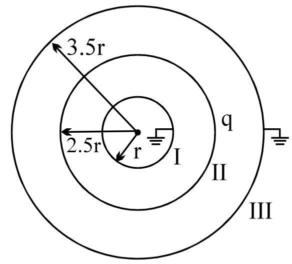
(i) radius a = b/e if the potential of the inner cylinder is to be maximum

(ii) radius a = $b/\sqrt{e}$ if the energy per unit length of the system is to be maximum.

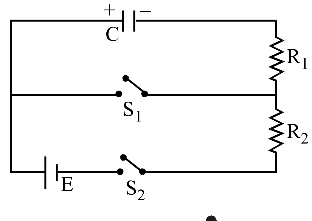
Q.13 Find the charge flown through the switch from A to B when it is closed.



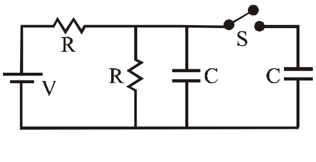
Q.14 Figure shows three concentric conducting spherical shells with inner and outer shells earthed and the middle shell is given a charge q. Find the electrostatic energy of the system stored in the region I and II.



Q.15 The capacitors shown in figure has been charged to a potential difference of V volts, so that it carries a charge CV with both the switches S_1 and S_2 remaining open. Switch S_1 is closed at t=0. At t=R_1C switch S_1 is opened and S_2 is closed. Find the charge on the capacitor at t=$2R_1C + R_2C$.



Q.16 In the figure shown initially switch is open for a long time. Now the switch is closed at t = 0. Find the charge on the rightmost capacitor as a function of time given that it was intially unchanged.



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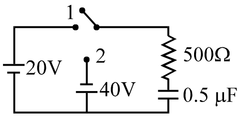
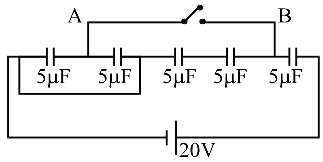
Q.17 In the given circuit, the switch is closed in the position 1 at t = 0 and then moved to 2 after 250 μs. Derive an expression for current as a function of time for t > 0. Also plot the variation of current with time.

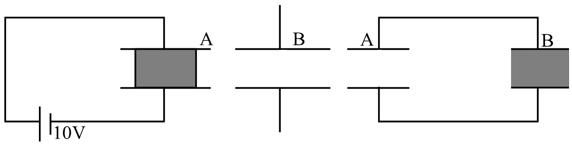


Q.18 Find the charge which flows from point A to B, when switch is closed.



EXERCISE # III

Q.1 Two parallel plate capacitors A & B have the same separation d = 8.85 × 10^{-4} m between the plates. The plate areas of A & B are 0.04 m^2 & 0.02 m^2 respectively. A slab of di-electric constant (relative permittivity) K=9 has dimensions such that it can exactly fill the space between the plates of capacitor B.



(i) the di-electric slab is placed inside A as shown in the figure (i) A is then charged to a potential difference of 110 volt. Calculate the capacitance of A and the energy stored in it.

(ii) the battery is disconnected & then the di-electric slab is removed from A . Find the work done by the external agency in removing the slab from A .

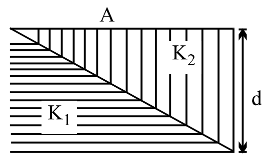
(iii) the same di-electric slab is now placed inside B, filling it completely. The two capacitors A & B are then connected as shown in figure (iii). Calculate the energy stored in the system. [JEE '93, 7]

Q.2 Two square metallic plates of 1 m side are kept 0.01 m apart, like a parallel plate capacitor, in air in such a way that one of their edges is perpendicular, to an oil surface in a tank filled with an insulating oil. The plates are connected to a battery of e.m.f. 500 volt . The plates are then lowered vertically into the oil at a speed of 0.001 m/s. Calculate the current drawn from the battery during the process. [di-electric constant of oil = 11, $\epsilon_0 = 8.85 \times 10^{-12}\ C^2/N^2 m^2$] [JEE '94, 6]

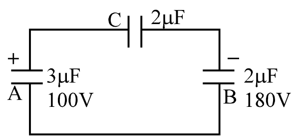
Q.3 A parallel plate capacitor C is connected to a battery & is charged to a potential difference V. Another capacitor of capacitance 2C is similarly charged to a potential difference 2V volt. The charging battery is now disconnected & the capacitors are connected in parallel to each other in such a way that the positive terminal of one is connected to the negative terminal of other. The final energy of the configuration is :

(A) zero (B) $\frac{3}{2}$ CV^2 (C) $\frac{25}{6}$ CV^2 (D) $\frac{9}{2}$ CV^2 [JEE '95, 1]

Q.4 The capacitance of a parallel plate capacitor with plate area 'A' & separation d is C. The space between the plates is filled with two wedges of di-electric constant K_1 & K_2 respectively. Find the capacitance of the resulting capacitor. [JEE '96, 2]



Q.5 Two capacitors A and B with capacities 3 μF and 2 μF are charged to a potential difference of 100 V and 180 V respectively. The plates of the capacitors are connected as shown in figure with one wire from each capacitor free. The upper plate of a is positive and that of B is negative. an uncharged 2 μF capacitor C with lead wires falls on the free ends to complete the circuit. Calculate :

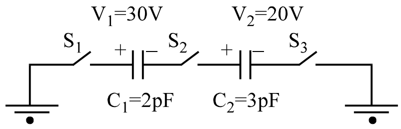


(i) the final charges on the three capacitors

(ii) The amount of electrostatic energy stored in the system before and after the completion of the circuit. [JEE '97 (cancelled)]

Q.6 An electron enters the region between the plates of a parallel plate capacitor at a point equidistant from either plate. The capacitor plates are 2×10^{-2} m apart & 10^{-1} m long . A potential difference of 300 volt is kept across the plates. Assuming that the initial velocity of the electron is parallel to the capacitor plates, calculate the largest value of the velocity of the electron so that they do not fly out of the capacitor at the other end. [JEE '97, 5]

Q.7 For the circuit shown, which of the following statements is true ?



(A) with S_1 closed, $V_1 = 15$ V, $V_2 = 20$ V
(B) with S_3 closed, $V_1 = V_2 = 25$ V
(C) with S_1 & S_2 closed, $V_1 = V_2 = 0$
(D) with S_1 & S_2 closed, $V_1 = 30$ V, $V_2 = 20$ V [JEE '99, 2]

Q.8 Calculate the capacitance of a parallel plate condenser, with plate area A and distance between plates d, when filled with a medium whose permittivity varies as ;

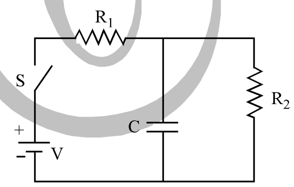
$$\in (x) = \in_0 + \beta x \qquad 0 < x < \frac{d}{2}$$

$$\in (x) = \in_0 + \beta\ (d - x) \qquad \frac{d}{2} < x < d\ .$$ [REE 2000, 6]

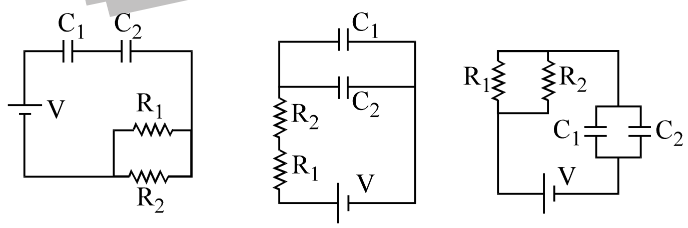
Q.9 Two identical capacitors, have the same capacitance C. One of them is charged to potential V_1 and the other to V_2. The negative ends of the capacitors are connected together. When the positive ends are also connected, the decrease in energy of the combined system is [JEE 2002 (Scr), 3]

(A) $\frac{1}{4}C\left(V_1^2 - V_2^2\right)$ (B) $\frac{1}{4}C\left(V_1^2 + V_2^2\right)$ (C) $\frac{1}{4}C\left(V_1 - V_2\right)^2$ (D) $\frac{1}{4}C\left(V_1 + V_2\right)^2$

Q.10 In the given circuit, the switch S is closed at time t = 0. The charge Q on the capacitor at any instant t is given by $Q(t) = Q_0\,(1 - e^{-\alpha t})$. Find the value of Q_0 and α in terms of given parameters shown in the circuit. [JEE 2005]



Q.11 Given : $R_1 = 1\Omega$, $R_2 = 2\Omega$, $C_1 = 2\mu F$, $C_2 = 4\mu F$
The time constants (in μS) for the circuits I, II, III are respectively



(I) (II) (III)

(A) 18, 8/9, 4 (B) 18, 4, 8/9
(C) 4, 8/9, 18 (D) 8/9, 18, 4 [JEE 2006]

ANSWER KEY

EXERCISE # I

Q.1 9J **Q.2** (a) 20 μC, (b) 0.3 mJ, (c) 0.6 mJ. (d) 60 μC

Q.3 3Q/2C **Q.4** 30 V **Q.5** C **Q.6** $\frac{1}{2}\frac{q^2 d}{\epsilon_0 A}$

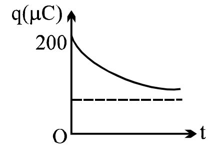
Q.7 0 **Q.8** $\frac{32}{23}$ μF

Q.9 (a) $\frac{100}{7}$ volts; (b) 28.56 μC, 42.84 μC, 71.4 μC, 22.88 μC **Q.10** 10 μC

Q.11 $\frac{25}{24}\frac{\varepsilon_0 A}{d}$ **Q.12** $\frac{8}{3}$μF **Q.13** $\frac{A\epsilon_0 V}{d}$, $-\frac{2A\epsilon_0 V}{d}$ **Q.14** 60 μc , A to B

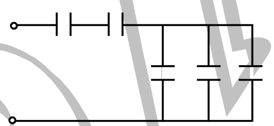
Q.15 150 μJ **Q.16** (i) $\frac{3}{2}CV^2$; (ii) $-\frac{1}{2}CV^2(K-1)$; $\frac{1}{6}(K+2)(K-1)CV^2$;

Q.17 (i) 5×10^4 V/m , 3×10^4 V/m; (ii) 35/9 **Q.18**



EXERCISE # II

Q.1 (a) 12 V, 9 V, 3 V, 13 V, 16 V , (b)



Q.2 $C = \frac{\epsilon S\pi K_1}{2d}$ **Q.3** (i) $\frac{5}{3}\left(\frac{\epsilon_0 A}{d}\right)$; (ii) $Q_3 = \frac{4}{3}\left(\frac{\epsilon_0 AV_a}{d}\right)$, $Q_5 = \frac{2}{3}\left(\frac{\epsilon_0 AV_a}{d}\right)$

Q.4 (i) 1.5×10^4 V/m, 4.5×10^4 V/m, (ii) 75 V, 225 V, (iii) 8×10^{-7} C/m^2

Q.5 2μA **Q.6** $W = \frac{1}{2}C_0 V_0^2\left(1-\frac{1}{K}\right)$ **Q.7** $C = C_0\left[\left(\frac{V_0}{V}\right)^{1/n} - 1\right] = 0.01078$ μF, n = 20

Q.8 $q_1 = \frac{C_1^2 V(C_2+C_3)}{C_1C_2+C_2C_3+C_1C_3}$ $q_2 = q_3$ $\frac{C_1C_2C_3V}{C_1C_2+C_2C_3+C_3C_1}$

Q.9 $\frac{\varepsilon_0 AV^2}{2d_1^2(d_0-d_1)}, \sqrt{\frac{K}{A\varepsilon_0}}\left(\frac{2}{3}d_0\right)^{3/2}, \left[\frac{Kd_1^3-\epsilon_0 AV^2}{md_1^3}\right]^{1/2}$ **Q.11** 12 volt **Q.13** 69 mC

Q.14 $U_I = \frac{3kq_1^2}{10r}$ *where* $q_1 = -\frac{4q}{25}$; $U_{II} = 2K(q+q_1)^2/35r$ **Q.15** $q = CE\left(1-\frac{1}{e}\right) + \frac{CV}{e^2}$

Q.16 $q = \frac{CV}{2}\left(1-\frac{1}{2}e^{-t/RC}\right)$

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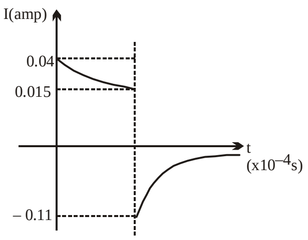
Q.17 For $t \le 250\ \mu s$, $I = 0.04\, e^{-4000\,t}$ amp ;

For $t > 250\ \mu s$, $I = -\ 0.11 e^{-4000(t-250)\times 10^{-6}}$ amp,



Q.18 $-\dfrac{400}{7}\ \mu C$

EXERCISE # III

Q.1 (i) 0.2×10^{-8} F, 1.2×10^{-5} J ; (ii) 4.84×10^{-5} J ; (iii) 1.1×10^{-5} J

Q.2 4.425×10^{-9} Ampere **Q.3** B **Q.4** $\dfrac{CK_1K_2}{(K_2 - K_1)}\ ln\ \dfrac{K_2}{K_1}$

Q.5 $Q_A = 90\ \mu C$, $Q_B = 150\ \mu C$, $Q_C = 210\ \mu C$, $U_i = 47.4$ mJ, $U_f = 18$ mJ

Q.6 $\dfrac{\sqrt{4.8}}{2\sqrt{9.1}} \times 10^8$ m/s **Q.7** D **Q.8** $\dfrac{\beta A}{2} \Big/ \ell n\left(\dfrac{2\in_0 + \beta d}{2\in_0}\right)$

Q.9 C **Q.10** $Q_0 = \dfrac{CVR_2}{R_1 + R_2}$ and $a = \dfrac{R_1 + R_2}{CR_1R_2}$ **Q.11** D