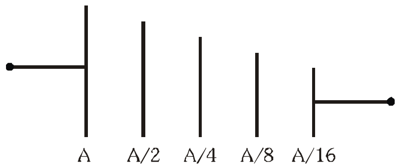
SECTION-I

Single Correct Answer Type **13 Q. [3 M (–1)]**

1. A 2-μF and a 1-μF capacitor are connected in series and charged from a battery. They store charges P and Q, respectively. When disconnected and charged separately using the same battery, they have charges R and S, respectively. Then :

(A) R > S > Q = P (B) P > Q > R = S (C) R > P = Q > S (D) R = P > S = Q

2. 5 Conducting plates each are placed face to face & equi-spaced at distance d. Area of each plate is half the previous plate. If area of first plate is A. Then the equivalent capacitance of the system shown is :-



(A) $\frac{\varepsilon_0 A}{d}$ (B) $\frac{\varepsilon_0 A}{10d}$ (C) $\frac{\varepsilon_0 A}{20d}$ (D) $\frac{\varepsilon_0 A}{30d}$

3. A parallel plate capacitor has an electric field of 10^5V/m between the plates. If the charge on the capacitor plate is 1μC, then the force on each capacitor plate is :-

(A) 0.1N (B) 0.05N (C) 0.02N (D) 0.01N

4. A dielectric slab is slowly inserted between the plates of a parallel plate capacitor, while the potential difference between the plates is held constant by a battery. As it is being inserted :

(A) the capacitance, the potential difference between the plates, and the charge on the positive plate all increase

(B) the capacitance, the potential difference between the plates, and the charge on the positive plate all decrease

(C) the potential difference between the plates increases, the charge on the positive plate decreases, and the capacitance remains the same

(D) the capacitance and the charge on the positive plate increase but the potential difference between the plates remains the same

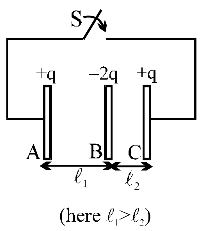
5. A dielectric slab is introduced between the plates of a capacitor. If the charge on the capacitor before the slab is introduced is q and the magnitude of the induced charge on the dielectric surface is q', then

(A) q' < q (always) (B) q' > q (always) (C) q' = q (always) (D) q' = 0

6. Three long concentric conducting cylindrical shells have radii R, 2R and $2\sqrt{2}$ R. Inner and outer shells are connected to each other. The capacitance across middle and inner shells per unit length is:

(A) $\frac{\frac{1}{3}\epsilon_0}{\ln 2}$ (B) $\frac{6\pi\epsilon_0}{\ln 2}$ (C) $\frac{\pi\epsilon_0}{2\ln 2}$ (D) None

7. Three long conducting plate A, B & C having charges +q, –2q & +q as shown in figure. Here plate A and C are fixed. If the switch S is closed. The middle plate (B) will start moving in



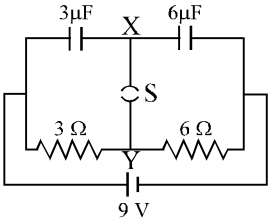
(A) Leftward direction

(B) Rightward direction

(C) will not move

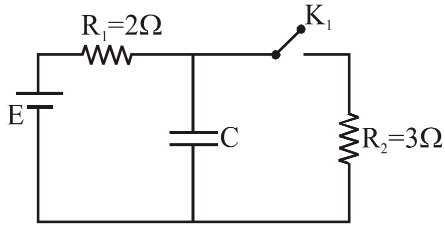
(D) First move leftward & then rightward

8. A circuit is connected as shown in the figure with the switch S open. When the switch is closed, the total amount of charge that flows from Y to X is :- **[IIT-JEE 2007]**



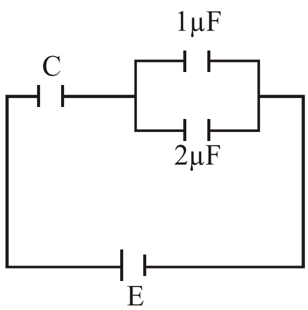
(A) 0 (B) 54 μC (C) 27 μC (D) 81 μC

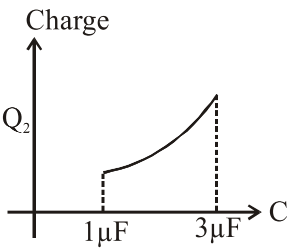
9. In the circuit shown in the figure K_1 is open. The charge on capacitor C in steady state is q_1. Now key is closed and at steady state charge on C is q_2. The ratio of charges q_1/q_2 is :

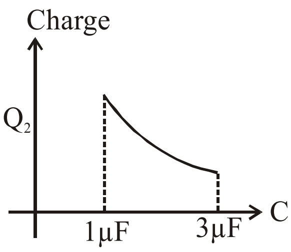


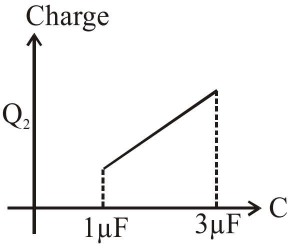
(A) 5/3 (B) 3/5 (C) 1 (D) 2/3

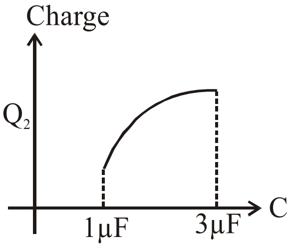
10. In the given circuit, charge Q_2 on the 2μF capacitor changes as C is varied from 1μF to 3μF. Q_2 as a function of 'C' is given properly by : (figures are drawn schematically and are not to scale) :- **[JEE-Main-2015]**



(A)


(B)


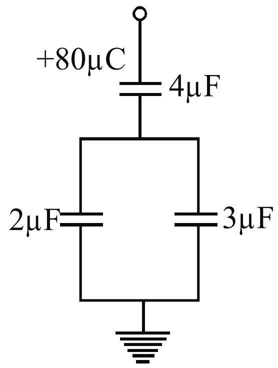
(C)


(D)


11. A parallel plate capacitor of capacitance 90 pF is connected to a battery of emf 20V. If a dielectric material of dielectric constant $K = \frac{5}{3}$ is inserted between the plates, the magnitude of the induced charge will be :- **[JEE-Main-2018]**

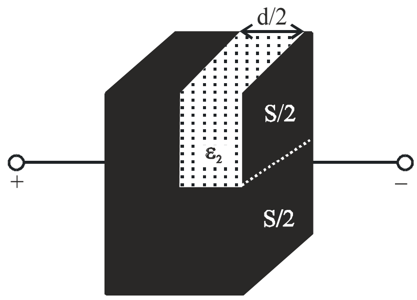
(A) 0.3 n C (B) 2.4 n C (C) 0.9 n C (D) 1.2 n C

12. In the given circuit, a charge of +80 μC is given to the upper plate of the 4μF capacitor. Then in the steady state, the charge on the upper plate of the 3μF capacitor is :- **[IIT-JEE 2012]**



(A) + 32 μC (B) + 40μC (C) +48μC (D) + 80μC

13. A parallel plate capacitor having plates of area S and plate separation d, has capacitance C_1 in air. When two dielectrics of different relative permittivities ($\varepsilon_1 = 2$ and $\varepsilon_2 = 4$) are introduced between the two plates as shown in the figure, the capacitance becomes C_2. The ratio $\frac{C_2}{C_1}$ is :- **[JEE-Advance 2015]**



(A) $\frac{6}{5}$ (B) $\frac{5}{3}$ (C) $\frac{7}{5}$ (D) $\frac{7}{3}$

Multiple Correct Answer Type **1 Q. [4 M (–1)]**

14. A parallel plate capacitor of plate area A and plate seperation d is charged to potential difference V and then the battery is disconnected. A slab of dielectric constant K is then inserted between the plates of the capacitor so as to fill the space between the plates. If Q, E and W denote, the magnitude of charge on each plate, the electric field between the plates (after the slab is inserted) and the work done on the system respectively in question, then in the process of inserting the slab

(A) $Q = \frac{\varepsilon_0 AV}{d}$ (B) $Q = \frac{\varepsilon_0 KAV}{d}$

(C) $E = \frac{V}{Kd}$ (D) $W = -\frac{\varepsilon_0 AV^2}{2d}\left(1 - \frac{1}{K}\right)$

Linked Comprehension Type (1 Para × 2Q.) [3 M (-1)]
(Single Correct Answer Type)

PARAGRAPH–1 (Q. No. 15 and 16)

Consider a simple RC circuit as shown in figure 1.

Process 1 : In the circuit the switch S is closed at t = 0 and the capacitor is fully charged to voltage V_0 (i.e., charging continues for time T >> RC). In the process some dissipation (E_D) occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is E_C.

Process 2 : In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time T >> RC. Then the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time T >> RC. The process is repeated one more time by raising the voltage to V_0 and the capacitor is charged to the same final voltage V_0 as in Process 1.

These two processes are depicted in Figure 2. **[JEE-Advance 2017]**

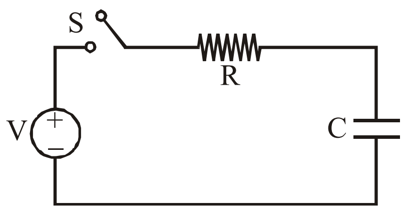


Figure 1

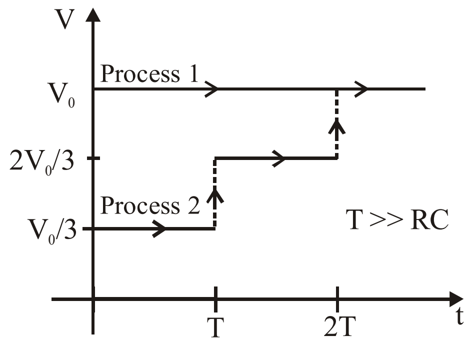


Figure 2

15. In Process 1, the energy stored in the capacitor E_C and heat dissipated across resistance E_D are related by:-

(A) $E_C = E_D$
(B) $E_C = 2E_D$
(C) $E_C = \frac{1}{2}E_D$
(D) $E_C = E_D \ln 2$

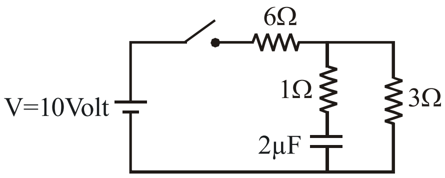
16. In Process 2, total energy dissipated across the resistance E_D is :-

(A) $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$
(B) $E_D = 3\left(\frac{1}{2}CV_0^2\right)$
(C) $E_D = \frac{1}{2}CV_0^2$
(D) $E_D = 3CV_0^2$

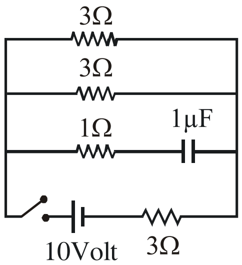
Matching List Type (4 × 4) 1 Q. [3 M (–1)]

17. Match the following. In each of the cases shown below, find the time constant of the circuit (in μs) after switch is closed.

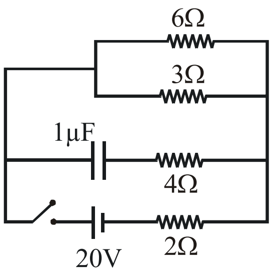
List-I **List-II**

(P) 

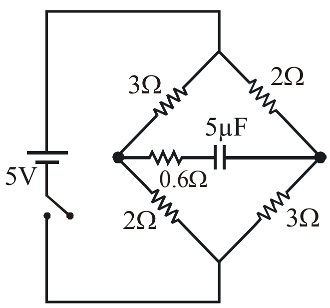
(1) 6

(Q) 

(2) 2

(R) 

(3) 5

(S) 

(4) 15

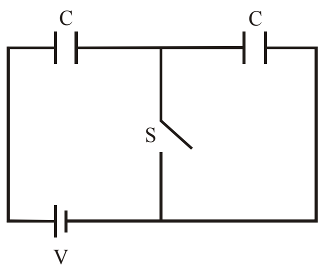
Codes :

	P	Q	R	S
(A)	1	2	1	4
(B)	3	1	4	2
(C)	1	2	3	4
(D)	2	4	1	3

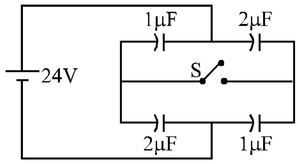
SECTION-II

Numerical Answer Type Question 4 Q. [3(0)]
(upto second decimal place)

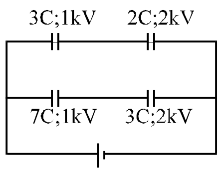
1. In the given circuit switch s is open initially. If C = 2μF and v = 3 volt. Then find heat produced (in μJ) in the circuit after closing the switch.



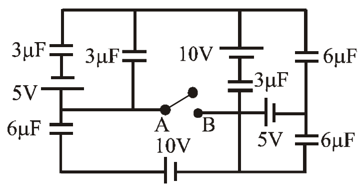
2. The connections shown in figure are established with the switch S open. How much charge will flow through the switch if it is closed ?



3. The diagram shows four capacitors with capacitances and break down voltages as mentioned. What should be the maximum value of the external emf source such that no capacitor breaks down?



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

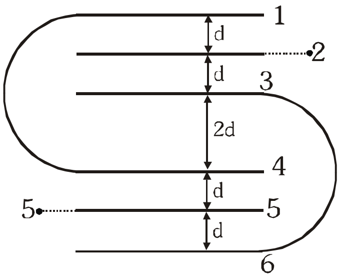


SECTION-III

Numerical Grid Type (Ranging from 0 to 9) 2 Q. [4 M (0)]

1. 2 conducting objects one with charge of +Q and another with –Q are kept on x-axis at x = 0 and x = 1 respectively. The electric field on the x-axis is given by $3Q\left(x^2+\frac{4}{3}\right)$. If the capacitance of this configuration of objects is C. Then fill $\frac{1}{C}$ (in F^{-1}) in OMR sheet.

2. There are six plates of equal area A and separation between the plates is d (d<<A) are arranged as shown in figure. The equivalent capacitance between points 2 and 5, is $\alpha \frac{\epsilon_0 A}{d}$. Then find the value of α.



SECTION-IV

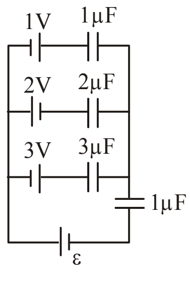
Matrix Match Type (4 × 5) **1 Q. [8 M (for each entry +2(0)]**

1.

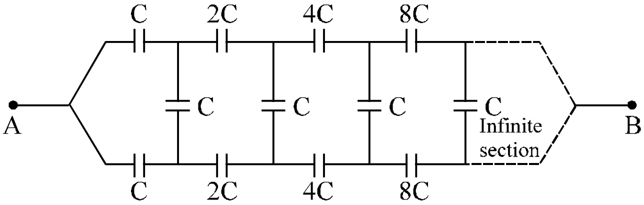
Column-I	**Column-II**
(A) Plates of an isolated, charged, parallel plate, air core capacitor are slowly pulled apart.	(P) Electric energy stored inside capacitor increases in the process.
(B) A dielectric is slowly inserted inside an isolated and charged parallel plate air cored capacitor to completely fill the space between plates.	(Q) Force between the two plates of the capacitor remain unchanged.
(C) Plates of a parallel plate capacitor connected across a battery are slowly pulled apart.	(R) Electric field in the region between plates remain unchanged.
(D) A dielectric slab is slowly inserted inside a parallel plate capacitor connected across a battery to completely fill the space between plates.	(S) Total electric energy stored inside capacitor decreases in the process.
	(T) Electric field in the region decreases.

Subjective Type **7 Q. [4 M (0)]**

1. In the figure shown, find the e.m.f. ε for which charge on 2μF capacitor is 4 μC.



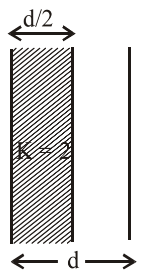
2. Find the equivalent capacitance of the circuit between point A and B.



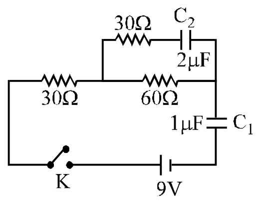
3. The plates of a parallel plate capacitor are given charges +4Q and –2Q. The capacitor is then connected across an uncharged capacitor of same capacitance as first one (= C). Find the final potential difference between the plates of the first capacitor.

4. 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, $\in_0 = 8.85 \times 10^{-12}\ C^2/N^2 m^2$]

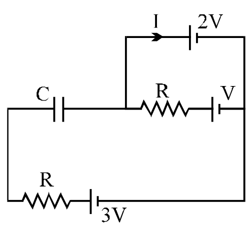
5. A certain series RC circuit is formed using a resistance R, a capacitor without dielectric having a capacitance C = 2F and a battery of emf E = 3V. The circuit is completed and it is allowed to attain the steady state. After this, at t = 0, half the thickness of the capacitor is filled with a dielectric of constant K = 2 as shown in the figure. The system is again allowed to attain a steady state. What will be the heat generated (in joule) in the circuit between t = 0 and t = ∞ ?



6. For the arrangement shown in the figure, the key is closed at t = 0. C_2 is initially uncharged while C_1 has a charge of 2μC.
(a) Find the current coming out of the battery just after switch is closed.
(b) Find the charge on the capacitors in the steady state condition.



7. In the RC circuit shown, what is the variation of the current I as a function of time? The capacitor is initially uncharged and the switch is closed at time t = 0 sec.



SECTION-I

Single Correct Answer Type **13 Q. [3 M (–1)]**

1. Ans. (A) **2. Ans. (D)** **3. Ans. (B)** **4. Ans. (D)**
5. Ans. (A) **6. Ans. (B)** **7. Ans. (B)** **8. Ans. (C)**
9. Ans. (A) **10. Ans. (D)** **11. Ans. (D)** **12. Ans. (C)**
13. Ans. (D)

Multiple Correct Answer Type **1 Q. [4 M (–1)]**

14. Ans. (A, C, D)

Linked Comprehension Type **(1 Para × 2Q.) [3 M (-1)]**
(Single Correct Answer Type)

15. Ans. (A) **16. Ans. (A)**

Matching List Type (4 × 4) **1 Q. [3 M (–1)]**

17. Ans. (C)

SECTION-II

Numerical Answer Type Question **4 Q. [3(0)]**
(upto second decimal place)

1. Ans. 4.50 **2. Ans.** 12μC **3. Ans.** 2.5 kV **4. Ans.** 69 mC

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) **2 Q. [4 M (0)]**

1. Ans. 5 **2. Ans.** 1

SECTION-IV

Matrix Match Type (4 × 5) **1 Q. [8 M (for each entry +2(0)]**

1. Ans. (A) → (PQR); (B) → (QST); (C) → (ST); (D) → (PR)

Subjective Type **7 Q. [4 M (0)]**

1. Ans. 6V, 34V **2. Ans.** (C) **3. Ans.** 3Q/2C

4. Ans. 4.425×10^{-9} Ampere **5. Ans.** $\frac{3}{4}$J

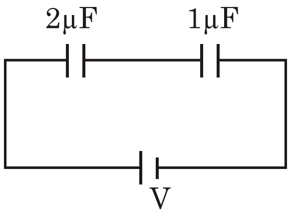
6. Ans. (a) $\frac{7}{50}$A or $\frac{11}{50}$A, (b) $Q_1 = 9\mu C$, $Q_2 = 0$ **7. Ans.** $\frac{V}{R}\left(e^{\frac{-t}{RC}} - 1\right)$

SOLUTIONS
SECTION-I

Single Correct Answer Type **13 Q. [3 M (–1)]**

1. Ans. (A)

Sol. When 2μF and 1 μF connected in series,



Charge on both capacitor will be same as charge on equivalent capacitor.

$$Q = C_{eq}V = \left(\frac{2\times 1}{2+1}\right)V = \frac{2V}{3}\mu C$$

$$P = Q = \frac{2V}{3}\mu C$$

When charged seperately from 'V'
Volt battery,
R = 2V = 2V μC
S = 1 × V = V μC
$\therefore$ R > S > Q = P

2. Ans. (D)

Sol. $\frac{1}{C_{eq}} = \frac{1}{\frac{\varepsilon_0 A}{2d}} + \frac{1}{\frac{\varepsilon_0 A}{4d}} + \frac{1}{\frac{\varepsilon_0 A}{8d}} + \frac{1}{\frac{\varepsilon_0 A}{16d}}$, $C_{eq} = \frac{\varepsilon_0 A}{30d}$

3. Ans. (B)

Sol. Force between the plates is given by

$F = \frac{\sigma^2 A}{2\in_0}$ or

$F = q\frac{E}{2} = \frac{1\times 10^{-6}\times 10^{5}}{2}$

[$\frac{E}{2}$ as electric field is due to charges on a single plate is to be written] $\frac{0.1}{2}N = 0.05N$

4. Ans. (D)

Sol. When dielectric slab is inserted slowly between the slab keeping battery connected, then potential difference remains same,
and C' = kC
then Q = C'V = kCV
$\because$ k > 1, then capacitance and charge both increases.

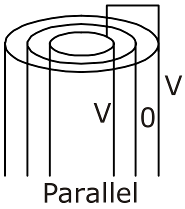
5. Ans. (A)

Sol. we know $q' = -q\left(1-\frac{1}{k}\right)$,

Therefore, $|q'| < |q|$

6. Ans. (B)

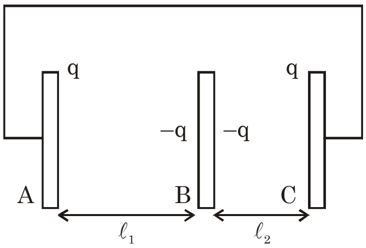
Sol. $\because C = \frac{2\pi \in_0}{\ell nb/a}$ $C_{eq} = \frac{2\pi \in_0}{\ell n\ 2R/R} + \frac{2\pi \in_0}{\ell n \frac{2\sqrt{2}}{2R}R}$



$= \frac{2\pi \in_0}{\ell n 2}[1+2] = \frac{6\pi \in_0}{\ell n 2}$

7. Ans. (B)

Sol.



$\because \ \ell_2 < \ell_1$, then attractive force aplied by plate 'C' on 'B' will be greater then attractive force applied by 'A' and 'B'. Hence plate 'B' moves rightward.

8. Ans. (C)

Sol. When S open

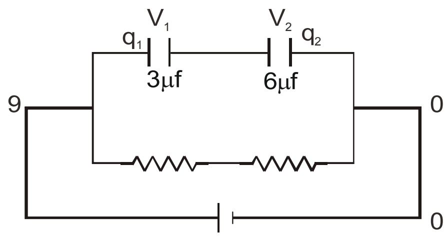
$q_1 = 18\mu f \Rightarrow q_2 = 18\mu f$

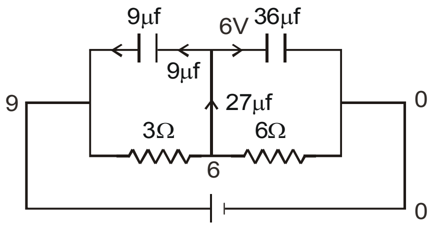
$V_1 : V_2 = \frac{1}{3} : \frac{1}{6}$

$V_1 : V_2 = 2 : 1$

$V_1 = \frac{2}{3} \times 9 = 6$ volt

$V_2 = 3$ volt

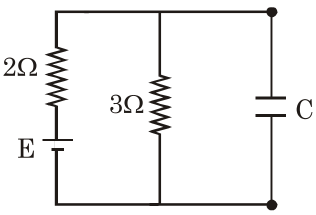




When S closed

9. Ans. (A)

Sol.



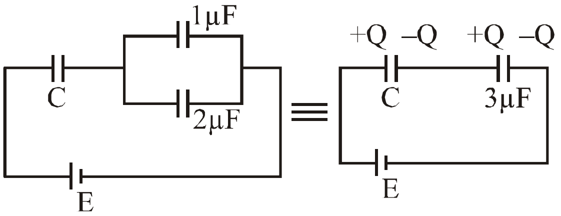
$q_1 = CE$, when switch is closed.

$E_{eq} = \frac{3E}{5}$

$q_2 = CE \times \frac{3}{5}$

10. Ans. (D)

Sol.



$C_{eq} = \frac{3C}{3+C}$ $Q = Ceq{\cdot}E$

$Q_2 = \frac{2CE}{(C+3)} = \frac{3CE}{(C+3)}$

$= 2E\left[1 - \frac{3}{C+3}\right]$

$Q_{2/\text{when } C = 1\mu F} = 2E\left[\frac{1}{4}\right] = \frac{E}{2}$

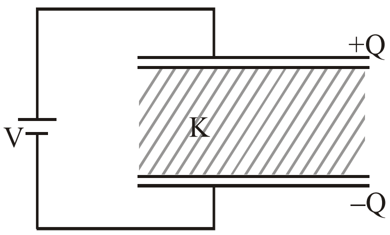
$Q_{2/\text{when } C = 3\mu F} = 2E\left[\frac{1}{2}\right] = E$

$\frac{dQ}{dC} = -\frac{2E\cdot 3}{(C+3)}(-1) = \frac{6E}{(C+3)^2} > 0$

$\frac{d^2Q}{dC^2} = \frac{6E(-2)}{(C+3)^3} = -\frac{12E}{(C+3)^2} < 0$

11. Ans. (D)

Sol.



$Q = (kC)\ V$

$= \left(\frac{5}{3}\times 90pF\right)(20V)$

$= 3000$ pC

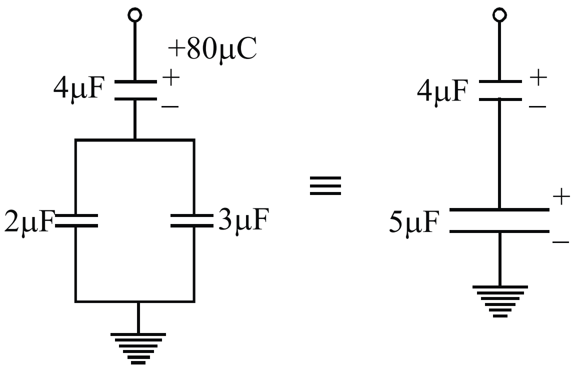
$= 3nC$

induced charges on dielectric

$Q_{ind} = Q\left(1 - \frac{1}{K}\right) = 3nC\left(1 - \frac{3}{5}\right) = 1.2\,nC$

12. Ans. (C)

Sol.



Charge on 4 μF and 5 μF capacitor will be same, because both are in series.

$q_{5\mu F} = 80\ \mu C$

∴ Potential difference across 5 μF

$$= \frac{q}{C} = \frac{80}{5} = 16V$$

∴ Charge on upper plate of

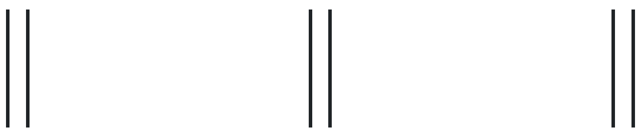
3μF capacitor = (3μF) (16V) = 48 μC

13. Ans. (D)

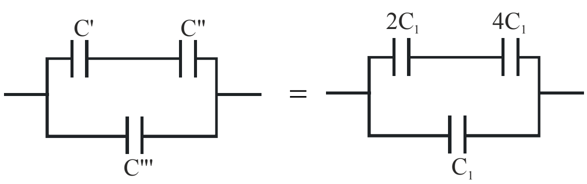
Sol. $\frac{5 \in_0}{d} = C_1$

in new setup we have 3 different setups

$5/2, \frac{d}{2}, \in_1$ $\qquad$ $5/2, \frac{d}{2}, \in_2$ $\qquad$ $5/2, d, \in_1$



$$C' = \frac{\frac{5}{2} \in_1 \in_0}{d/2} = 2C_1 \qquad C'' = \frac{\frac{5}{2} \in_2 \in_0}{d/2} = 4C_1 \qquad C''' = \frac{\frac{5}{2} \in_1 \in_0}{d} = C_1$$



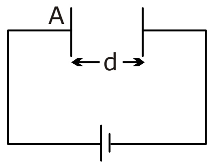
$$C_2 = \left(\frac{1}{2C_1} + \frac{1}{4C_1}\right)^{-1} + C_1 = \frac{14}{6}C_1 = \frac{7}{3}C_1$$

$$\therefore \frac{C_2}{C_1} = \frac{7}{3}$$

Multiple Correct Answer Type 1 Q. [4 M (–1)]

14. Ans. (A, C, D)

Sol. $U = \frac{1}{2}CV^2$



$U_i = \frac{1}{2}\frac{\varepsilon_0 A}{d}V^2$

After inserting slab Q = const.

$U_f = \frac{Q^2}{2C}$ $\{Q = \frac{\varepsilon_0 AV}{d}\}$

$U_f = \frac{\varepsilon_0^2 A^2 V^2 d}{2d^2 k\varepsilon_0 A} = \frac{\varepsilon_0 Av^2}{2dk}$

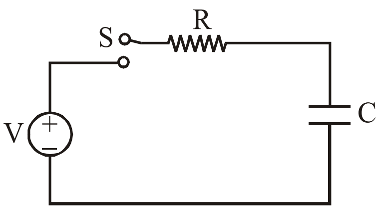
W.D. = $U_f - U_i$

$= -\frac{\varepsilon_0 AV^2}{2d}\left(1-\frac{1}{k}\right)$

Linked Comprehension Type (1 Para × 2Q.) [3 M (-1)]
(Single Correct Answer Type)

15. Ans. (A)

Sol.



When switch is closed for a very long time capacitor will get fully charged & charge on capacitor will be q = CV

Energy stored in capacitor $\in_C = \frac{1}{2}CV^2$ ...(i)

Work done by battery (ω) = Vq = VCV = CV^2

dissipated across resistance $\in_D$ = (work done by battery) – (energy store)

$\in_D = CV^2 - \frac{1}{2}CV^2 = \frac{1}{2}CV^2$ ...(ii)

from (i) & (ii)

$\in_D = \in_C$

16. Ans. (A)

Sol. For process (1)

Charge on capacitor = $\frac{CV_0}{3}$

energy stored in capacitor = $\frac{1}{2}C\frac{V_0^2}{9} = \frac{CV_0^2}{18}$

work done by battery = $\frac{CV_0}{3} \times \frac{V}{3} = \frac{CV_0^2}{9}$

Heat loss = $\frac{CV_0^2}{9} - \frac{CV_0^2}{18} = \frac{CV_0^2}{18}$

For process (2)

Charge on capacitor = $\frac{2CV_0}{3}$

Extra charge flow through battery = $\frac{CV_0}{3}$

Work done by battery : $\frac{CV_0}{3} . \frac{2V_0}{3} = \frac{2CV_0^2}{9}$

Final energy store in capacitor : $\frac{1}{2} C\left(\frac{2V_0}{3}\right)^2 = \frac{4CV_0^2}{18}$

energy store in process 2 : $\frac{4CV_0^2}{18} - \frac{CV_0^2}{18} = \frac{3CV_0^2}{18}$

Heat loss in process (2) = work done by battery in process (2) – energy store in capacitor process (2)

$= \frac{2CV_0^2}{9} - \frac{3CV_0^2}{18} = \frac{CV_0^2}{18}$

For process (3)

Charge on capacitor = CV_0

extra charge flow through battery : $CV_0 - \frac{2CV_0}{3} = \frac{CV_0}{3}$

work done by battery in this process : $\left(\frac{CV_0}{3}\right)(V_0) = \frac{CV_0^2}{3}$

find energy store in capacitor : $\frac{1}{2} CV_0^2$

energy stored in this process : $\frac{1}{2} CV_0^2 - \frac{4CV_0^2}{18} = \frac{5CV_0^2}{18}$

heat loss in process (3) : $\frac{CV_0^2}{3} - \frac{5CV_0^2}{18} = \frac{CV_0^2}{18}$

Now total heat loss (E_D) : $\frac{CV_0^2}{18} + \frac{CV_0^2}{18} + \frac{CV_0^2}{18} = \frac{CV_0^2}{6}$

final energy store in capacitor : $\frac{1}{2} CV_0^2$

so we can say that $E_D = \frac{1}{3}\left(\frac{1}{2} CV_0^2\right)$

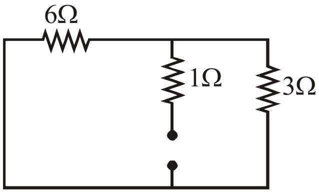
Matching List Type (4 × 4)　　　　1 Q. [3 M (–1)]

17. Ans. (C)

Sol. To find time-constant of R.C. circuit, short-circuit the battery and find equivalent resistance across the capacitor,

$\tau = R_{eq}C$

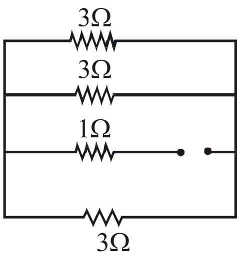
(P)



$\Rightarrow R_{eq} = 3\Omega$

$\therefore \tau = 3 \times 2 = 6\ \mu s$

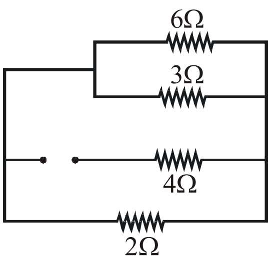
(Q)



$\Rightarrow R_{eq} = 2\Omega$

$\therefore \tau = 2 \times 1 = 2\ \mu s$

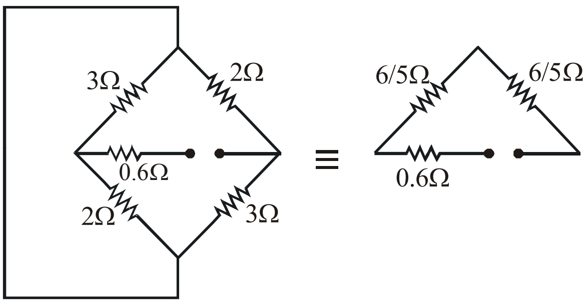
(R)



$\Rightarrow R_{eq} = 5\Omega$

$\therefore \tau = 5 \times 1 = 5\ \mu s$

(S)



$\Rightarrow R_{eq} = 3\Omega$

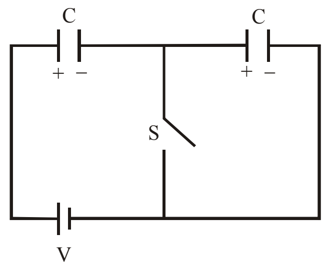
$\therefore \tau = 5 \times 3 = 15\ \mu s$

SECTION-II

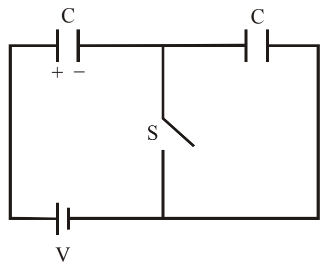
Numerical Answer Type Question **4 Q. [3(0)]**
(upto second decimal place)

1. **Ans. 4.50**

Sol.



initial



final

$$U_i = \frac{1}{2}C.\left(\frac{V}{2}\right)^2 .2 \qquad U_f = \frac{1}{2}CV^2$$

$$= \frac{CV^2}{4}$$

$$W_{Cell} = V.\Delta q = V.\left(CV - \frac{CV}{2}\right) = \frac{CV^2}{2}$$

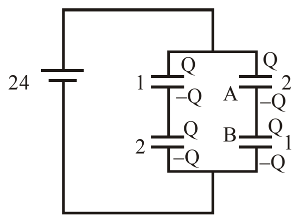
Now $U_i + W = U_f + H$

$$\therefore \qquad H = \frac{CV^2}{4} = \frac{2\times 9}{4} = 4.50$$

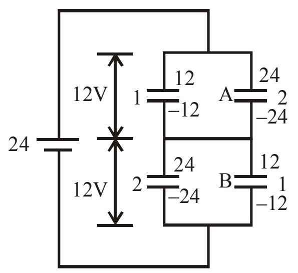
2. Ans. 12μC

Sol. Initial circuit

$$Q = \left(\frac{2\times 1}{2+1}\right)\times 24 = 16 \text{ C}$$



Final circuit



Initially charge on A & B combinted is 0 and finally at is –12
So charge flowing is 12 μC

3. **Ans.** 2.5 kV

Sol. $Q_{1max} = 3\ C \times 10^3\ C.$

$Q_{2max} = 4\ C \times 10^3\ C.$

Q_{max} for first branch $3\ C \times 10^3\ C$

$$V_{max_1} = \frac{3C \times 10^3 \times 5C}{6C^2} = \frac{5}{2}KV$$

Similarly for second branch

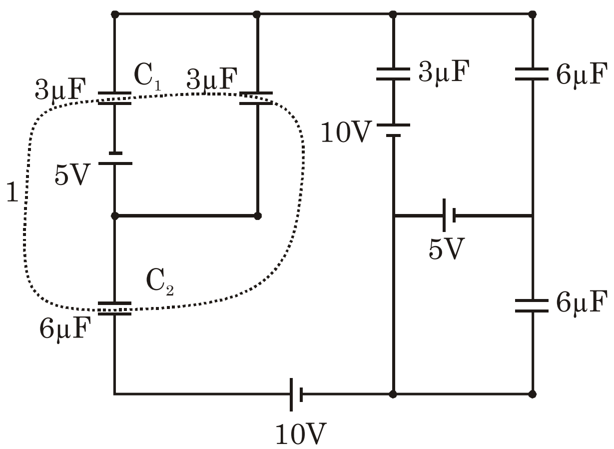
$Q_{3_{max}} = 7C \times 10^3\ C$ $Q_{4_{max}} = 6C \times 10^3 C$

$$V_{max_2} = \frac{6C \times 10^3}{21C^2} \times 10C = \frac{20}{7}kV$$

The two branches are in parallel. So in order to find max value of voltage for which no capacitor breaks down $V_{max_1} < V_{max_2}$.

4. **Ans.** 69 mC

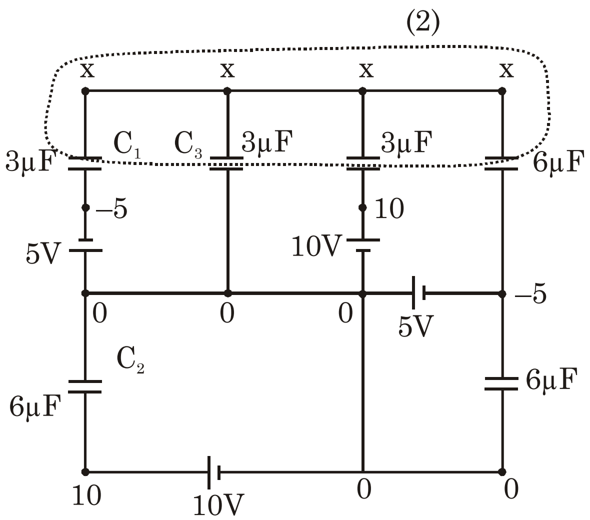
Sol.



∵ Sum & charge on a closed isolated system is conserved

i.e. $q_i = 0$

After switch is closed



On loop (2)
(x + 5)3 + (x – 0)3 + (x + 0)3 + (x + 5) 6 = 0
$\Rightarrow$ x = –1V
(q_f) = Sum of charges on C_1, C_2 and C_3
= (– 5 + 1)3 + (0 + 1)3 + (0 – 10) × 6
= 69 μF
$\therefore$ Charge flown = $q_i - q_f$ = 69 μF

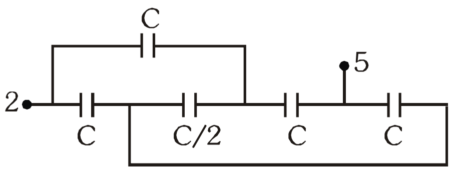
SECTION-III

Numerical Grid Type (Ranging from 0 to 9) 2 Q. [4 M (0)]

1. **Ans.** 5

Sol. $C = \frac{Q}{V} = \frac{Q}{\int_0^1 E.dx} = \frac{1}{5}$

2. **Ans. 1**

Sol. 

Redraw the circuit $C_{eq} = C = \frac{\in_0 A}{d}$

SECTION-IV

Matrix Match Type (4 × 5) 1 Q. [8 M (for each entry +2(0)]

1. **Ans. (A) →(PQR); (B) →(QST); (C) →(ST); (D) →(PR)**

Sol. **For (A) :** Field remains same as charge is same. Hence energy stored increases. (P) & (Q) as field is same and (R).

For (B) : Since distance between plate and charge remains same and field decreases, (S & T)

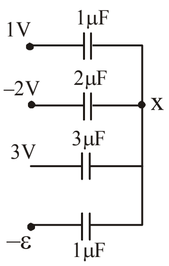
$F = \frac{Q^2}{2 \in_0 A}$, charge is same hence force remain same (Q).

For (C) : Since connected to battery P.D. remains same and as distance increases the electric field decreases. (T) Also as capacitance decreases the charge also decreases decreasing the force of interaction and energy inside decrease (S).

For (D) : Capacitance increases and P.D. remaining same, thus charge and energy increases (P) and force of interaction increases. Field remains same as distance and P.D. remains same (R) and energy increases.

Subjective Type 7 Q. [4 M (0)]

1. **Ans.** 6V, 34V

Sol. 

Charge on an isolated system is conserved,
$\therefore$ (x – 1) 1 + (x + 2) × 2 + (x – 3) × 3 + (x + ε) × 1 = 0

$\Rightarrow 7x + \varepsilon - 6 = 0$ .... (i)

$\because$ Charge on 2μF capacitor is 4μC

if $q = +4\mu C$

$(x + 2) \times 2 = 4\mu C$

$x = 0 \Rightarrow$ from (i) $\varepsilon = 6$ V

if $q = -4\mu C$, then

$(x + 2) \times 2 = -4 \Rightarrow x = -4$

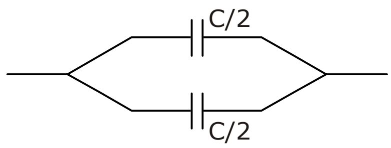
from (i) $\varepsilon = 34$ V

2. **Ans.** (C)

Sol. $\therefore \frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{2C} + \frac{1}{4C} \ldots\ldots$

$= \frac{1}{C\left[1 + \frac{1}{2} \ldots\right]}$

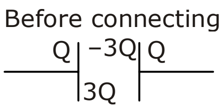
$\frac{1}{C_{eq}} = \frac{1}{C\left(1 - \frac{1}{2}\right)} \Rightarrow C_{eq} = \frac{C}{2}$

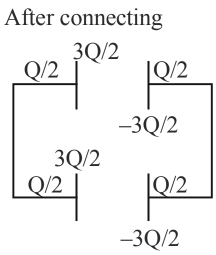


$C_{eq} = C$

3. **Ans.** 3Q/2C

Sol.





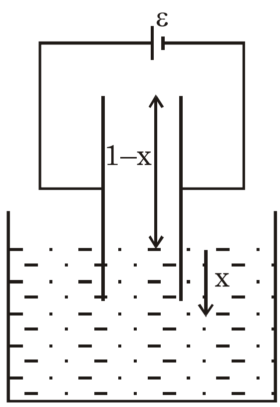
V = 3Q\2C

4. **Ans.** 4.425×10^{-9} Ampere

Sol. $C_{eq} = \frac{\epsilon_0 (1 - x) \times 1}{d} + \frac{k \epsilon_0 (x \times 1)}{d}$

$= \frac{\epsilon_0}{d}[1 - x + kx]$

$= \frac{\epsilon_0}{d}[1 + (k - 1)x]$



$q = C_{eq}\varepsilon$

$\frac{dq}{dt} = \frac{dC_{eq}}{dt}\varepsilon$

$\Rightarrow \frac{dq}{dt} = \frac{\epsilon_0}{d}(k - 1)\varepsilon$

$\Rightarrow I = \frac{(8.85 \times 10^{-12})(11 - 1) \times 500}{0.01}$

$I = 4.425 \times 10^{-9}$ A

5. **Ans.** $\frac{3}{4}J$

Sol. Initial charge on capacitor = CE

Initial potential energy of capacitor = $\frac{CE^2}{2}$

Now $C = \frac{\varepsilon_0 A}{d}$

And new capacitance : $C' = \frac{\varepsilon_0 A}{d/2}$, in series with $\frac{\varepsilon_0 kA}{d/2}$

$\Rightarrow C' = \frac{2\varepsilon_0 A}{d}$ series $\frac{4\varepsilon_0 A}{d}$

$= \frac{\varepsilon_0 A}{d}\left(\frac{2\times 4}{2+4}\right) = \frac{4\varepsilon_0 A}{3d} = \frac{4}{3}C \Rightarrow$ New charge $= \frac{4}{3}CE$

New energy $= \frac{1}{2}\times\frac{4}{3}CE^2 = \frac{2}{3}CE^2$

Now $W_{but} = \Delta H + \Delta U$

$\Rightarrow E\left(\frac{4}{3}CE - CE\right) = \Delta H + \frac{2}{3}CE^2 - \frac{1}{2}CE^2 \Rightarrow \Delta H = \frac{1}{6}CE^2$

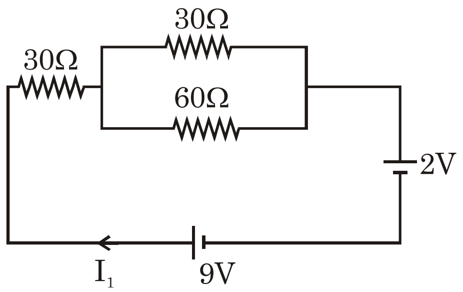
6. **Ans.** (a) $\frac{7}{50}A$ or $\frac{11}{50}A$, (b) $Q_1 = 9\mu C$, $Q_2 = 0$

Sol. (a) Potential difference across 'C_1' just before swithc is closed.

$\Delta V = \frac{q}{C} = \frac{2}{1} = 2V$

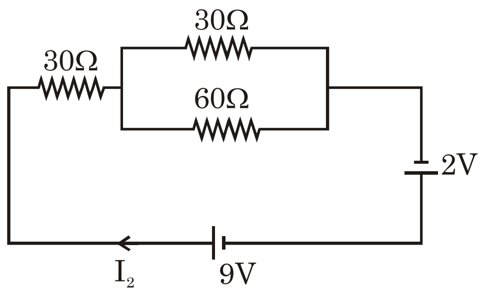
∴ Just after switch is closed

Case-I :



$I_1 = \frac{7}{50}A$

Case-II :



$$I_2 = \frac{9}{50} A$$

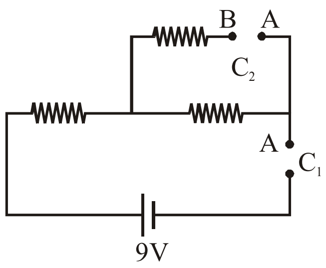
(b) In steady state there will be no current in the circuit

P.d across $C_2 = 0$

So charge = 0

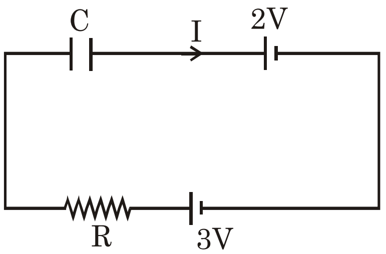
P.d across $C_1 = 9V$

$Q = 9\ \mu C$

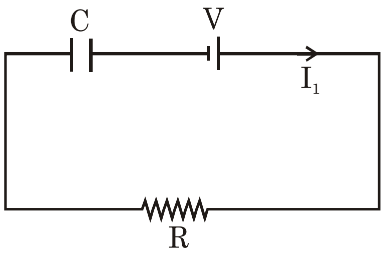


7. Ans. $\frac{V}{R}\left(e^{\frac{-t}{RC}} - 1\right)$

Sol.



$\equiv$



$$I_1 = \frac{V}{R}\left(1 - e^{-\frac{t}{RC}}\right)$$

$$\because I = -I_1 = \frac{V}{R}\left(e^{-\frac{t}{RC}} - 1\right)$$