Physicsaholics

DPP – 5 (Capacitor)

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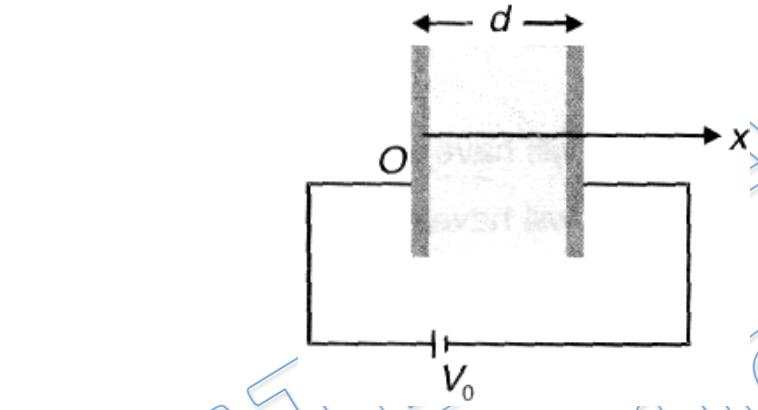
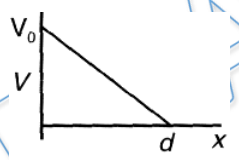
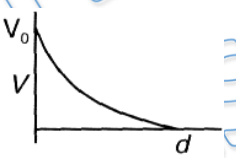
Q 1. The gap between plates of a parallel plate capacitor is filled with dielectric whose dielectric constant varies uniformly from K to 2K in a direction perpendicular to the plates. Potential difference between plates is V. Correct variation of potential with x is





(a)



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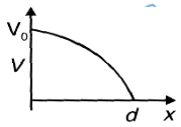
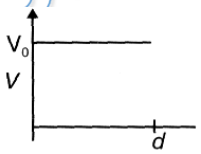
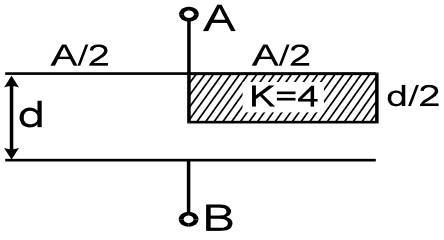


(c)



(d)

Q 2. Find the equivalent capacitance between terminals 'A' and 'B'. The letters have their usual meaning.



(a) $\frac{6}{5}\frac{\epsilon_0 A}{d}$ (b) $\frac{13}{10}\frac{\epsilon_0 A}{d}$

(c) $\frac{10}{7}\frac{\epsilon_0 A}{d}$ (d) $\frac{5}{7}\frac{\epsilon_0 A}{d}$

Q 3. Column-I gives certain situations in which capacitance of a capacitor is changed by different means. Column-II gives resulting effect under different conditions. Match the statements in column-I with the corresponding statements in column-II

	Column-I		**Column-II**
(A)	The plates of a plane parallel plate capacitor are slowly pulled apart. Then the magnitude of electric field intensity inside the capacitor	(p)	Increases if the capacitor is maintained at constant charge.
(B)	The plates of a plane parallel plate capacitor are slowly pulled apart. Then the potential energy stored in the capacitor	(q)	Decreases if the capacitor is maintained at constant charge.
(C)	The capacitance of an air filled plane parallel plate capacitor on insertion of dielectric.	(r)	Increases if the capacitor is maintained at constant potential difference.
(D)	A dielectric slab is inserted inside an air filled plane parallel plate capacitor. The potential energy stored in the capacitor.	(s)	Decreases if the capacitor is maintained at constant potential difference.

Q 4. The capacitance of a parallel plate capacitor is C_0 when the plates has air between them. This region is now filled with a dielectric slab of dielectric constant K and capacitor is connected with battery of EMF E and zero internal resistance. Now slab is taken out, then

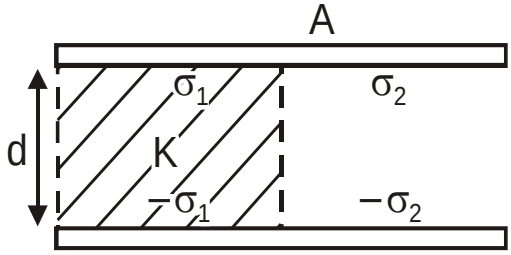
(a) charge $EC_0(K-1)$ flows through the cell

(b) energy $E^2C_0(K-1)$ is absorbed by the cell

(c) the energy stored in the capacitor is reduced by $E^2C_0(K-1)$

(d) the external agent has to do $E^2C_0(K-1)$ amount of work to take out the slab

Q 5. A parallel plate capacitor of area A and separation d is charged to potential difference V and removed from the charging source. A dielectric slab of constant K = 2, thickness d and area $\frac{A}{2}$ is inserted, as shown in the figure. Let σ_1 be free charge density at the conductor-dielectric surface and σ_2 be the charge density at the conductor-vacuum surface.



(a) The electric field have the same value inside the dielectric as in the free space between the plates.

(b) The ratio $\frac{\sigma_1}{\sigma_2}$ is equal to $\frac{2}{1}$.

(c) The new capacitance is $\frac{3\epsilon_0 A}{2d}$

(d) The new potential difference is $\frac{2}{3}$ V

Q 6. An uncharged parallel plate capacitor is connected to a battery. The electric field between the plates is 10v/m. Now a dielectric of dielectric constant 2 is inserted between the plates filling the entire space. The electric field between the plates now is

(a)5 V/m (b) 20 V/m

(c) 10 V/m (d) none of these

Q 7. A parallel plate capacitor (without dielectric) is charged and disconnected from a battery. Now a dielectric is inserted between the plates. The electric force on a plate of the capacitor will:

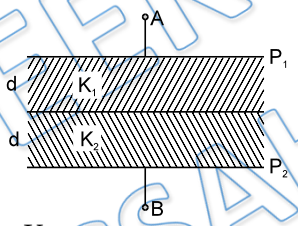
(a) decrease

(b) increase

(c) remain same

(d) depends on the width of the dielectric

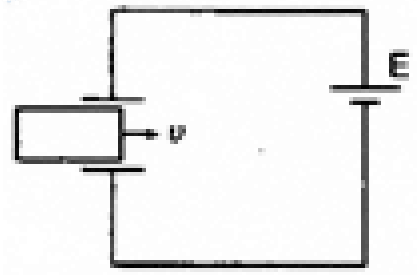
Q 8. In the figure shown P_1 and P_2 are two conducting plates having charges of equal magnitude and opposite sign. Two dielectrics of dielectric constant K_1 and K_2 fill the space between the plates as shown in the figure. The ratio of electrical energy in 1st dielectric to that in the 2nd dielectric is

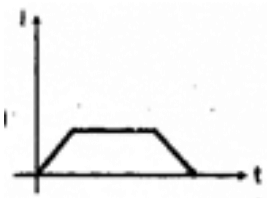


(a) 1 : 1 (b) $K_1 : K_2$

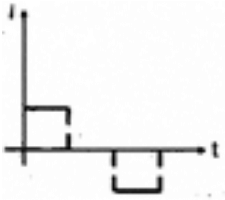
(c) $K_2 : K_1$ (d) $K_2^2 : K_1^2$

Q 9. A dielectric slab of area A and thickness d is inserted between the plates of capacitor of area 2A and distance between plates d with a constant speed v as shown in figure. The capacitor is connected to a battery of emf E. The current in the circuit varies with time as





(a)



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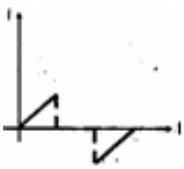
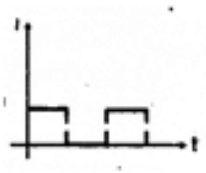
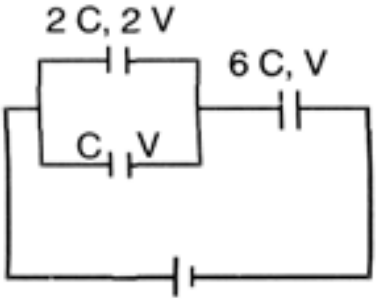


(c)



(d)

Q 10. Diagram shows three capacitors with capacitance and breakdown voltage mentioned. What should be maximum value of the external emf of source such that no capacitor breakdown?

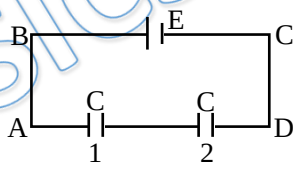


(a) V
(b) 2 V
(c) 1.5 V
(d) 4 V

Q 11. A dielectric of dielectric constant K = 2 is pasted on conductor sphere of radius 1 meter to make its radius 2 meter. Find capacitance of system ?

(a) $\frac{4}{27}$ nF (b) $\frac{27}{4}$ nF (c) 4 nF (d) None of these

Q 12. In the adjoining figure, capacitor (1) and (2) have a capacitance 'C' each. When the dielectric of dielectric constant K is inserted between the plates of one of the capacitor, the total charge flowing through battery is

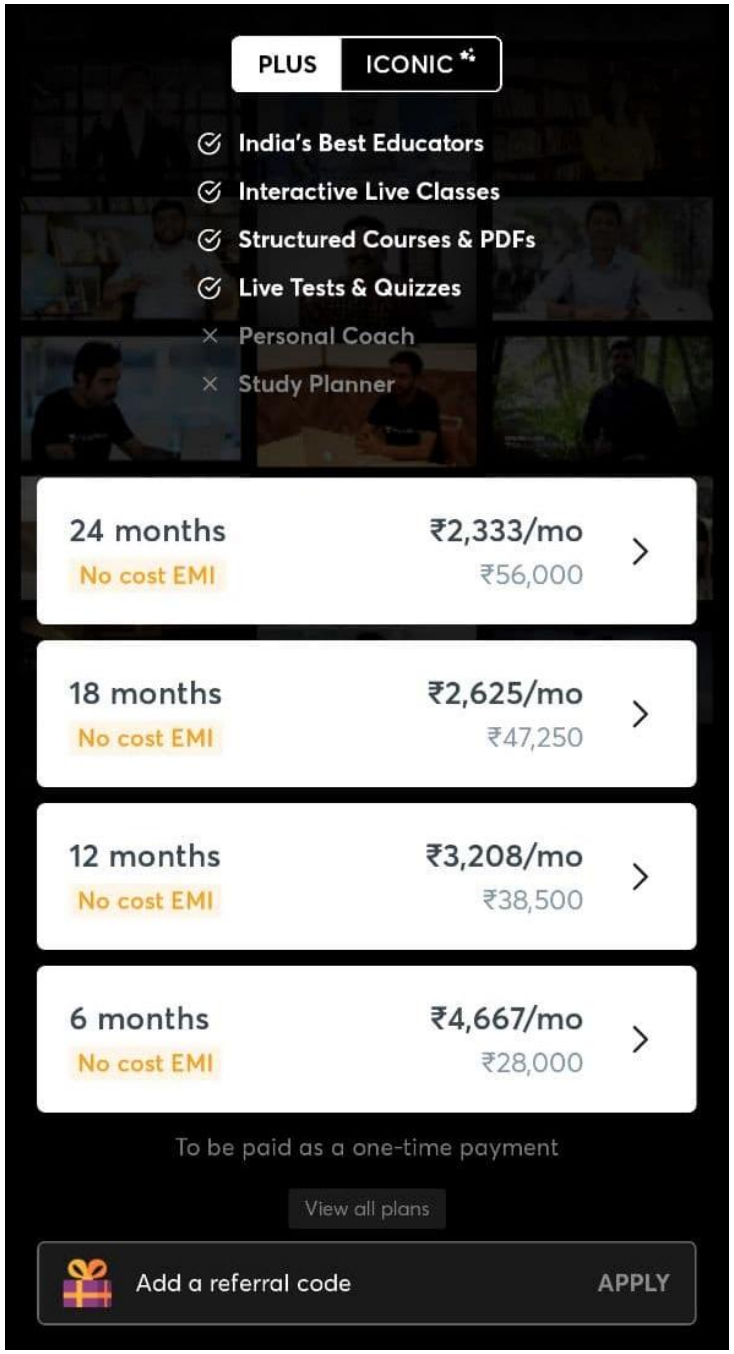


(a) $\frac{KCE}{K+1}$ from B to C
(b) $\frac{KCE}{K+1}$ from C to B
(c) $\frac{(K-1)CE}{2(K+1)}$ from B to C
(d) $\frac{(K-1)CE}{2(K+1)}$ from C to B

Answer Key

Q.1 b	Q.2 b	Q.3	Q.4 a, b	Q.5 a, b, c, d
Q.6 c	Q.7 c	Q.8 c	Q.9 b	Q.10 c
Q.11 a	Q.12 d			

Q.3 (A) – s, ; (B) – p, s ; (C) – p, r ; (D) – q, r



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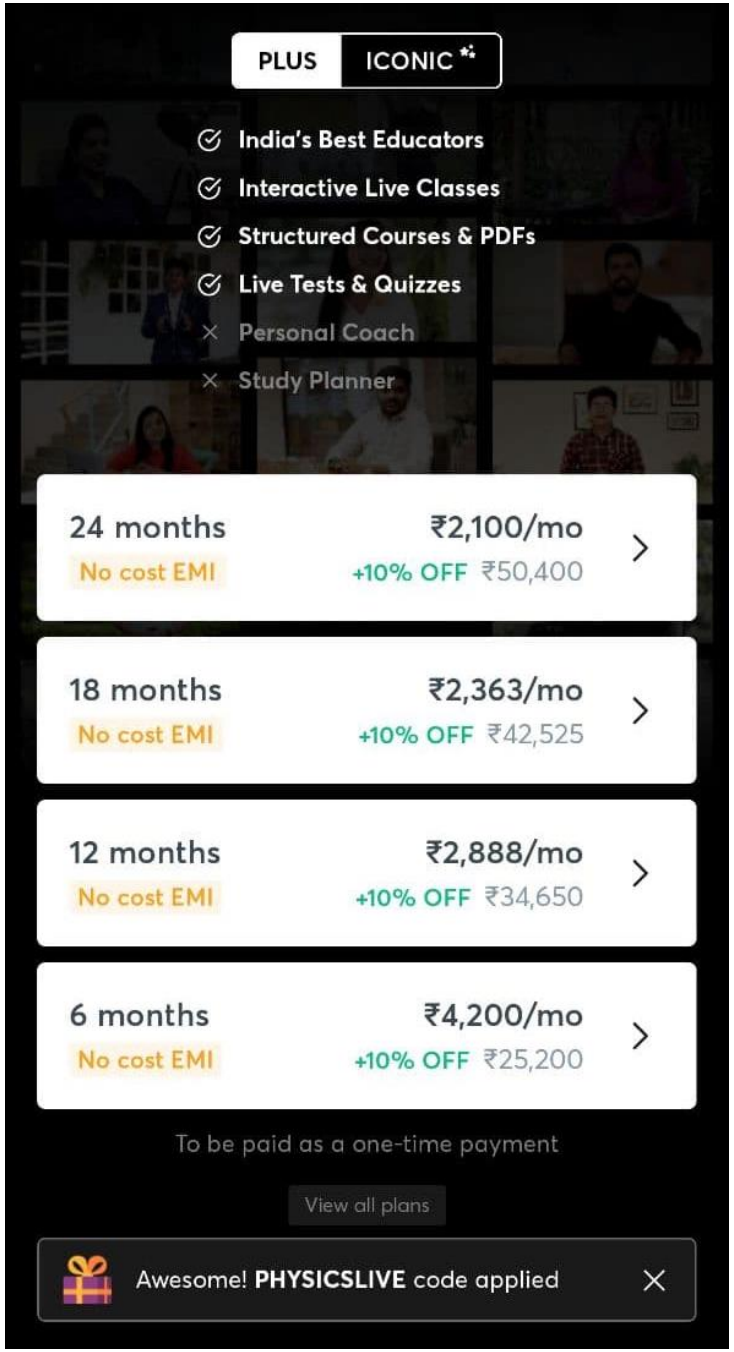


Written Solution

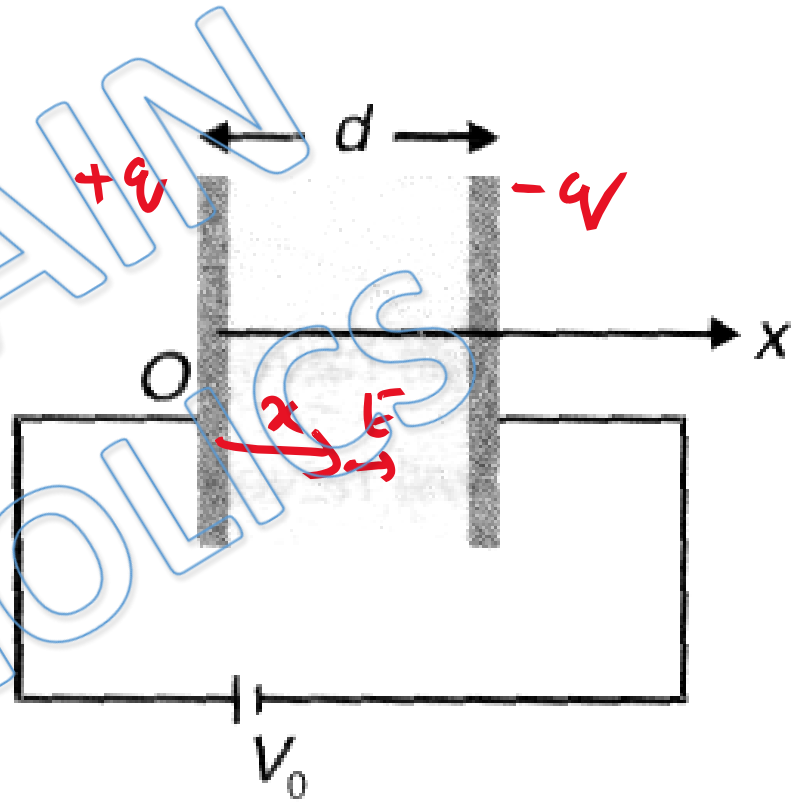
DPP-5 Capacitor- Effect of Dielectric on Capacitor

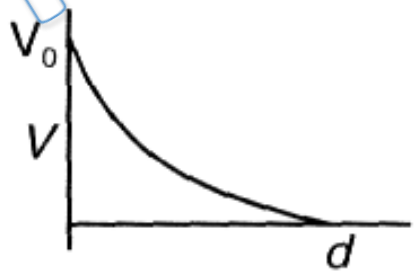
By Physicsaholics Team

1) Electric field at $x = x$

$$E = \frac{\sigma}{A\epsilon_0 K}$$

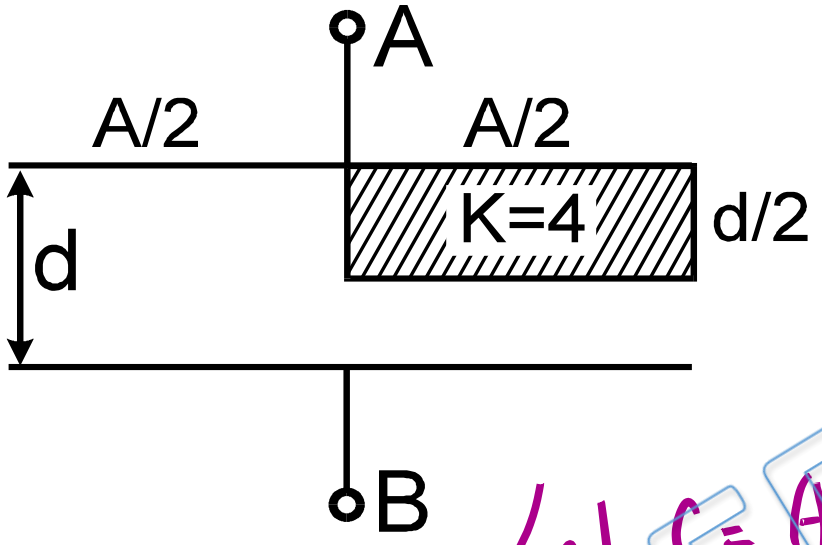
Since K is linearly increasing with x, | Slope | of V-x graph (ie. E) will decrease on increasing x.



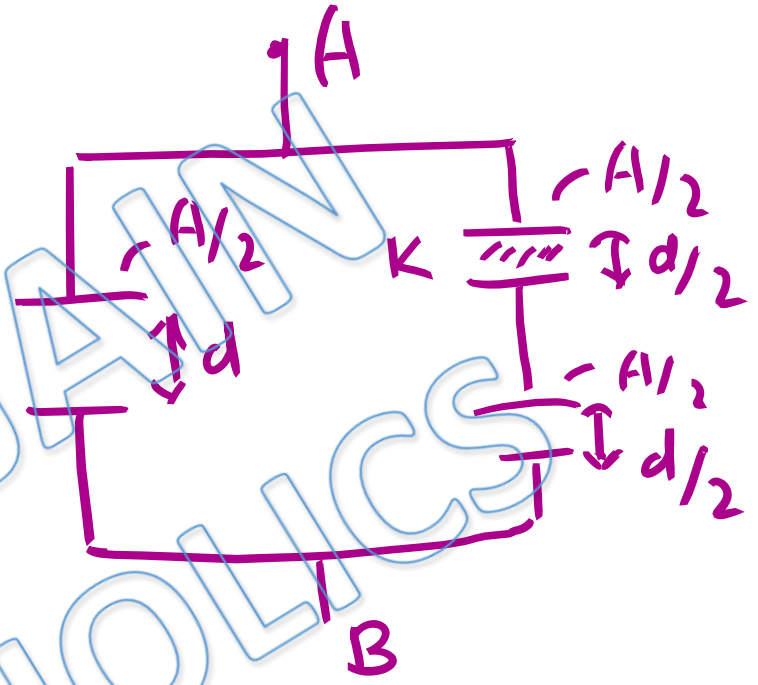


Ans (b)

2)

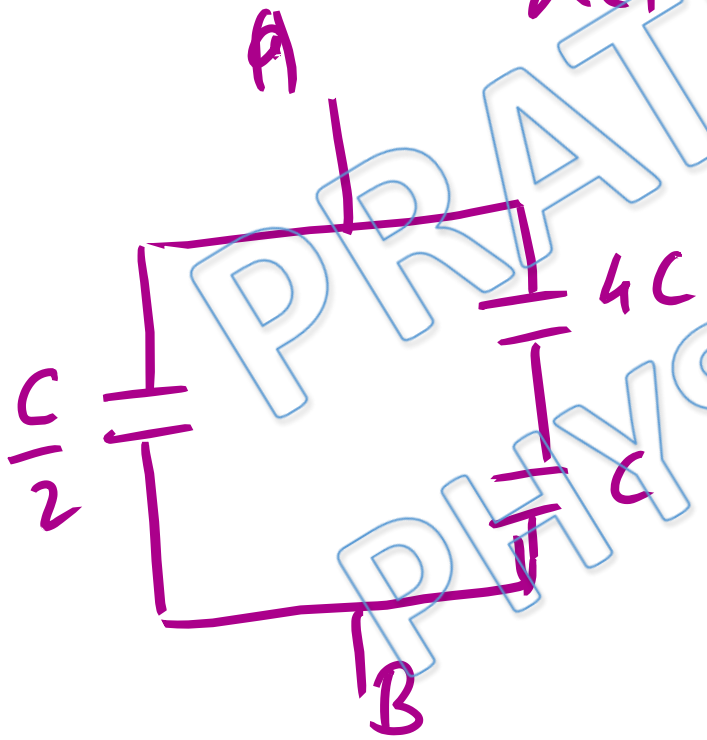


$=$



Let $C = \frac{A\epsilon_0}{d}$

$=$



$C_{eq} = \frac{C}{2} + \frac{C \times 4C}{5C} = \frac{C}{2} + \frac{4C}{5}$

$= \frac{5C + 8C}{10} = \frac{13C}{10}$

$= \frac{13A\epsilon_0}{10d}$

Ans(b)

3) (A) field b/w plates $E = \frac{q}{A\epsilon_0} \Rightarrow$ Constant if q is Constant.

also $E = \frac{V}{d} \Rightarrow$ decreases if V is Constant.

(B) Energy stored $U = \frac{q^2 d}{2A\epsilon_0} \Rightarrow$ increases if q is Constant.

also $U = \frac{1}{2}V^2 \frac{A\epsilon_0}{d} \Rightarrow$ decreases if V is Constant.

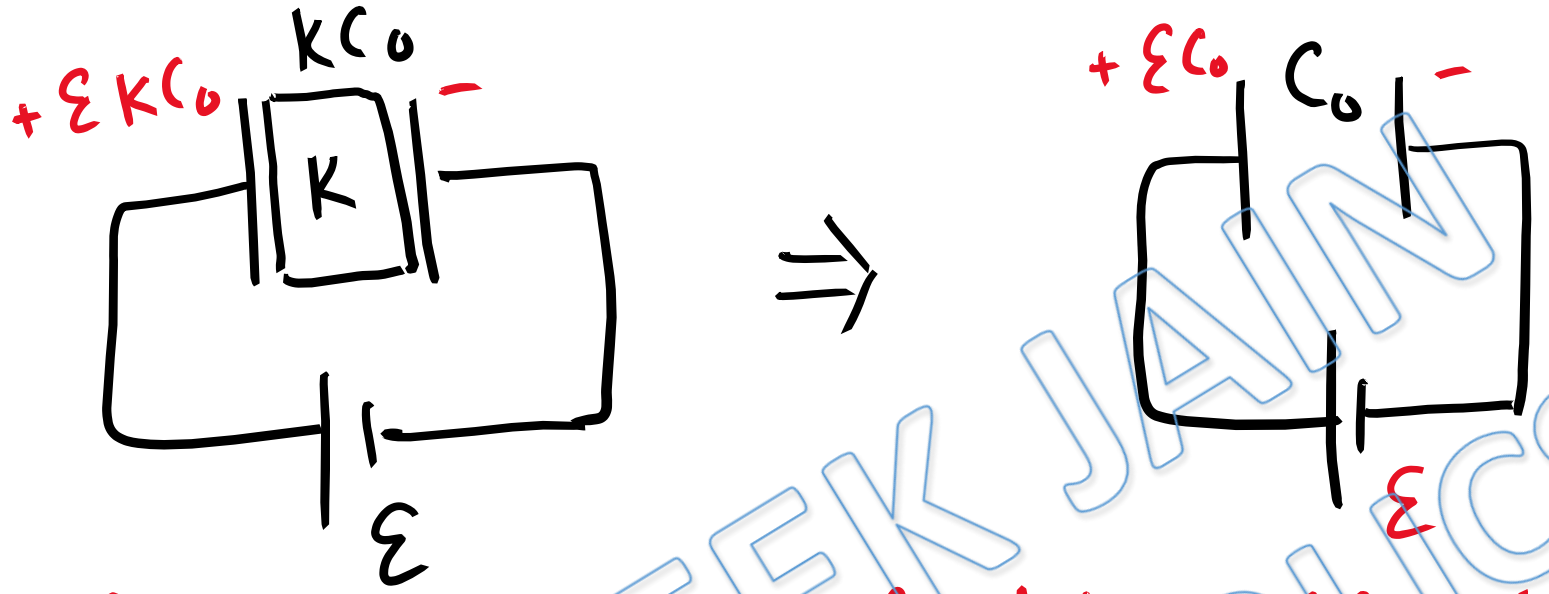
(C) On insertion of dielectric Capacitance increases.

(D) $U = \frac{q^2}{2C} \Rightarrow$ If q is Constant, on inserting dielectric C ↑ & U ↓,

also $U = \frac{1}{2} V^2 C$ if V is Constant

On inserting dielectric C_T & U_T.

4)



If charge q is supplied by cell during removal of dielectric $\varepsilon K C_0 + q = \varepsilon C_0$

$\Rightarrow q = \varepsilon C_0 (1-K) = -\varepsilon C_0 (K-1)$

$\Rightarrow$ charge $\varepsilon C_0 (K-1)$ is taken back by cell.

Work done by cell $= q\varepsilon = -\varepsilon^2 C_0 (K-1)$

Energy absorbed by cell $= \varepsilon^2 C_0 (K-1)$

$U_i = \frac{1}{2}\varepsilon^2 C_0 K$, $U_f = \frac{1}{2}\varepsilon^2 C_0$

Reduction in energy stored $= U_i - U_f$

$= \frac{1}{2}\varepsilon^2 C_0 (K-1)$

by Conservation of energy →

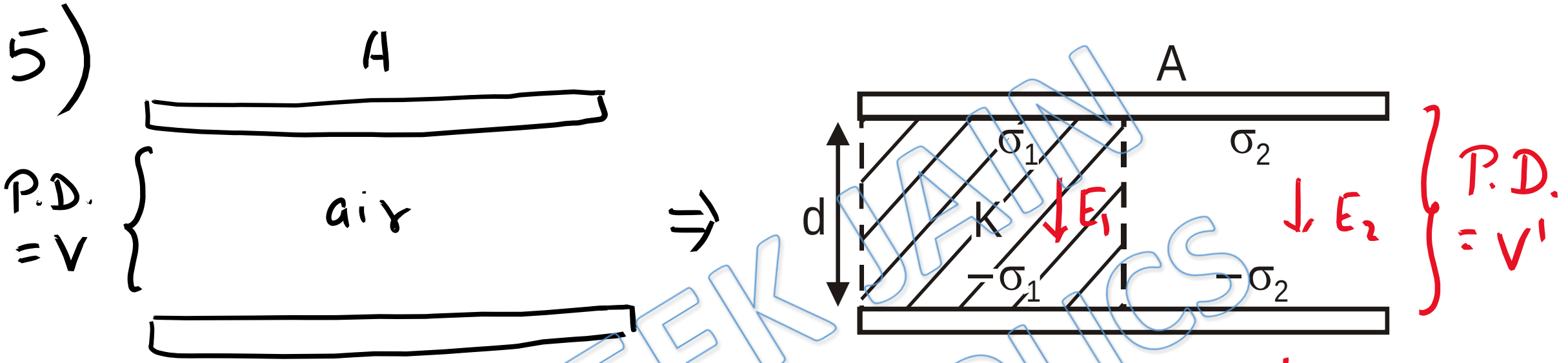
$W_{ele} + W_{ext} = \Delta U + \Delta H$ (ΔH is zero Since motion is slow & $(i \to 0)$)

$-\varepsilon^2 C_0 (K-1) + W_{ext} = -\frac{1}{2}\varepsilon^2 C_0 (K-1)$

$W_{ext} = \frac{1}{2}\varepsilon^2 C_0 (K-1)$

FINS(a, b)

5)



Here, $E_1 = E_2 = \frac{V'}{d}$

Since $E_1 = E_2$

$\frac{\sigma_1}{A\epsilon_0 K} = \frac{\sigma_2}{A\epsilon_0}$

$\Rightarrow \frac{\sigma_1}{\sigma_2} = K = 2$

new Capacitance $C' = C_1 + C_2 = \frac{A/2\,\epsilon_0 K}{d} + \frac{A/2\,\epsilon_0}{d}$

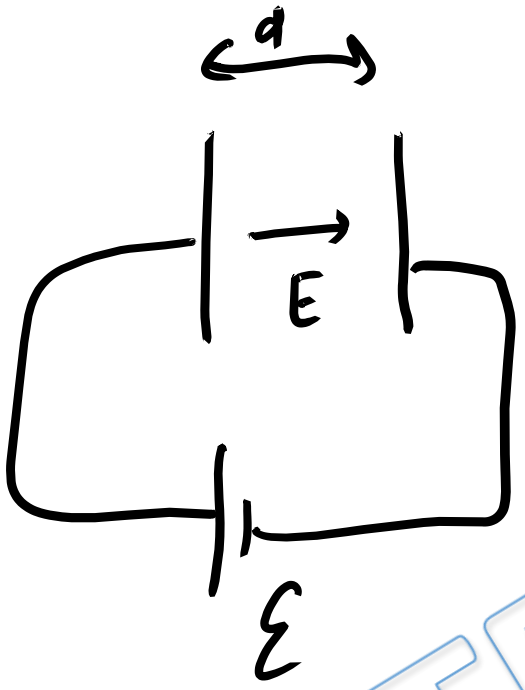
$$C' = \frac{A\epsilon_0}{2d}(K+1) = \frac{3A\epsilon_0}{2d}$$

new P.D. $V' = \frac{q}{C'} = \frac{CV}{C'}$

$$= \frac{\frac{A\epsilon_0}{d} \times V}{3A\epsilon_0/2d} = \frac{2V}{3}$$

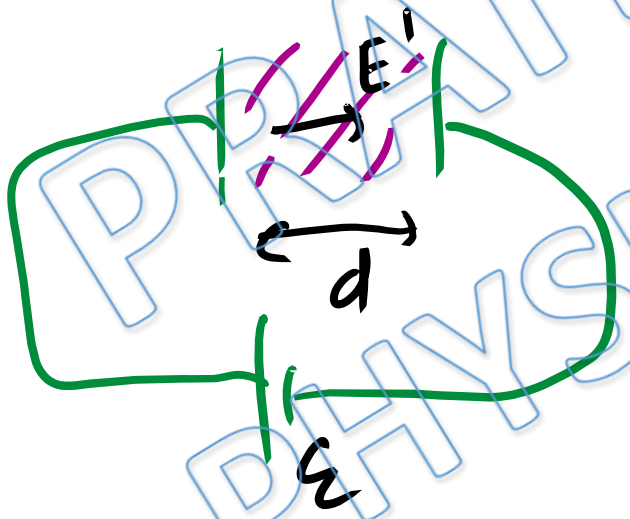
Ans (a, b, c, d)

6)



$$E = \frac{\varepsilon}{d} = 10\ V/m$$

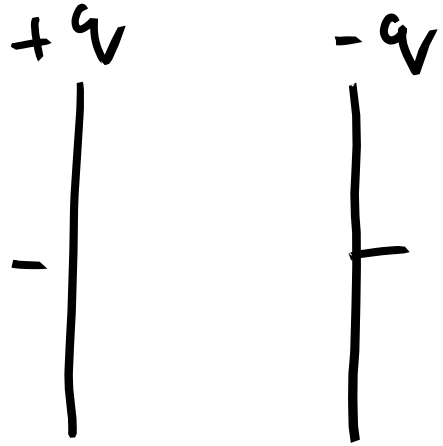
⇒



$$E' = \frac{\varepsilon}{d} = 10\ V/m$$

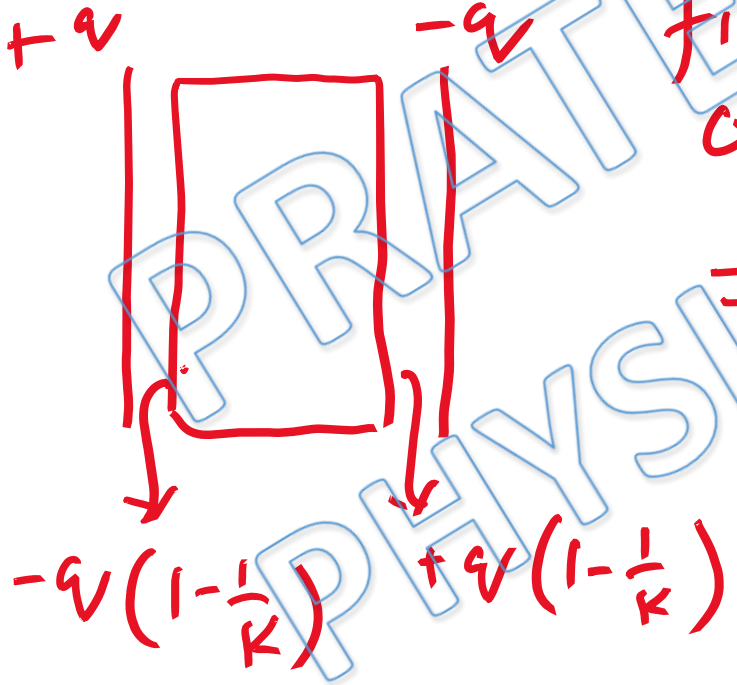
Ans (c)

7)



force on -ve plate

$$= \frac{q^2}{2A\epsilon_0}$$



field on -ve plate due to all other charges

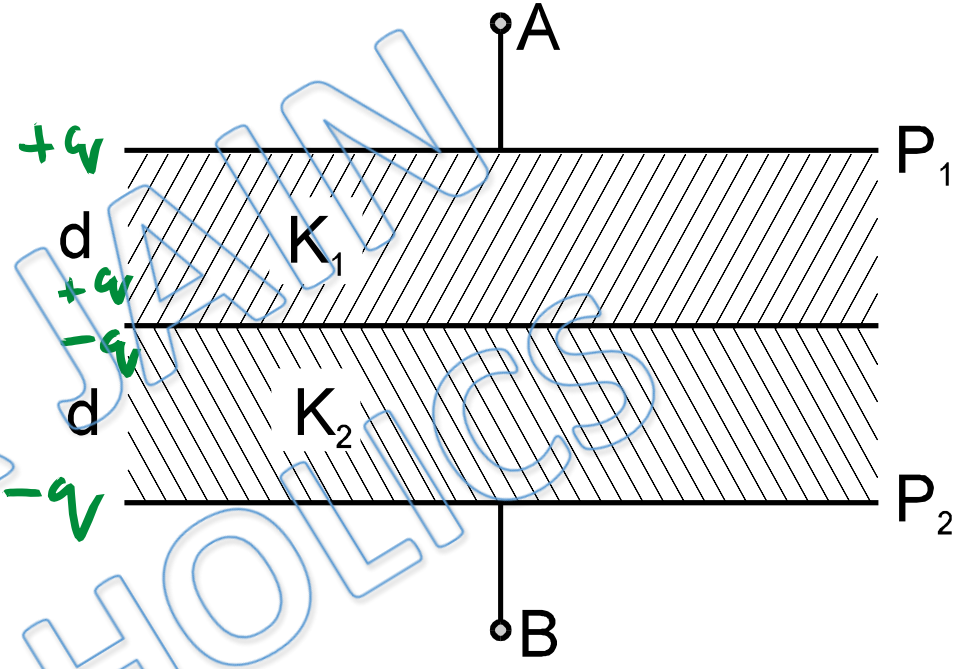
$$= \frac{q - q\left(1-\frac{1}{K}\right) + q\left(1-\frac{1}{K}\right)}{2A\epsilon_0} = \frac{q}{2A\epsilon_0}$$

force on -ve plate $= \frac{q^2}{2A\epsilon_0}$

Ans(c)

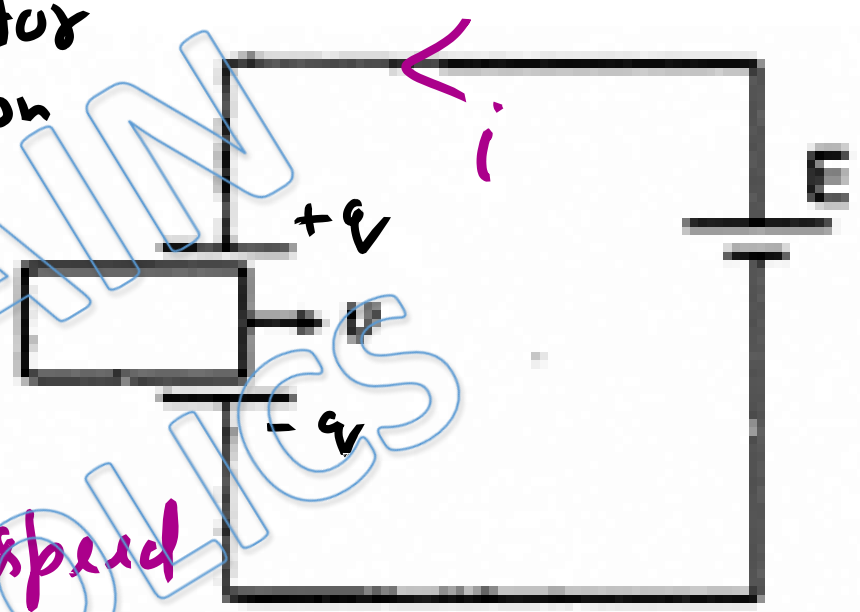
8) $\frac{U_1}{U_2} = \frac{q^2/2C_1}{q^2/2C_2}$

$= \frac{C_2}{C_1} = \frac{K_2}{K_1}$



Ans(c)

9) If length of slab inside capacitor is x, $\frac{dC}{dx}$ = Constant (well known fact)



$q = \varepsilon C$

$i = \frac{dq}{dt} = \varepsilon \frac{dC}{dt}$

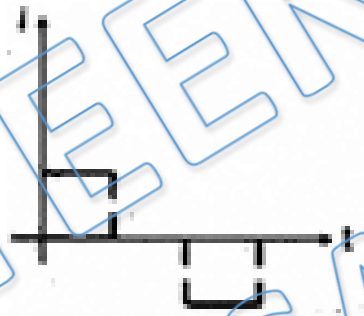
$= \varepsilon \left(\frac{dC}{dx}\right)\left(\frac{dx}{dt}\right) = \varepsilon v \left(\frac{dC}{dx}\right)$ = Constant during insertion.

v = speed

when slab is comming in, $C \uparrow$, due to which q increases & i flow in forward direction.

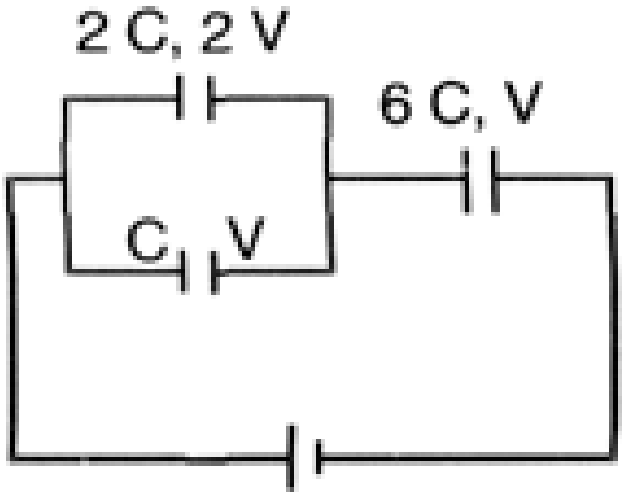
when slab is completely inside capacitor, C does not change on shifting slab $\Rightarrow q$ is Constant & $i = 0$.

when slab moves out, Capacitance decreases, V decreases ⇒ Current flows in reverse direction.

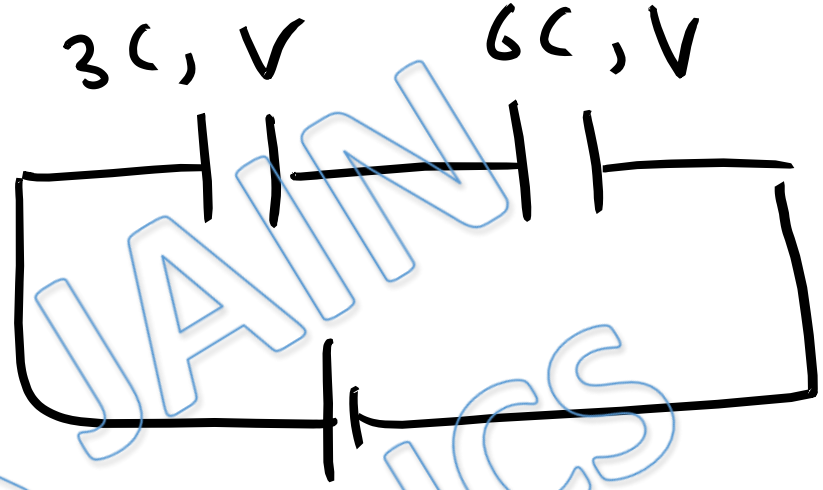


Ans (b)

10)



$\Rightarrow$



In Series Combination q_{max} = Smaller of C_1V_1 & C_2V_2

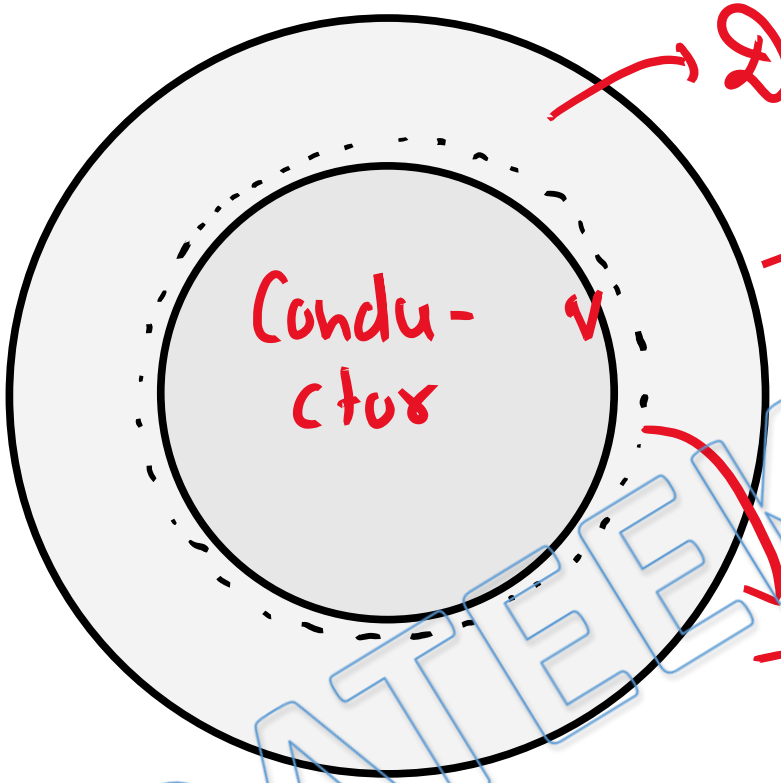
= Smaller of 3CV & 6CV

= 3CV

$$V_{max} = \frac{q_{max}}{C_{eff}} = \frac{3CV}{2C} = \frac{3V}{2}$$

Ans(c)

11)



$+q\left(1-\frac{1}{K}\right)=q/2$

$-q\left(1-\frac{1}{K}\right)=-q/2$

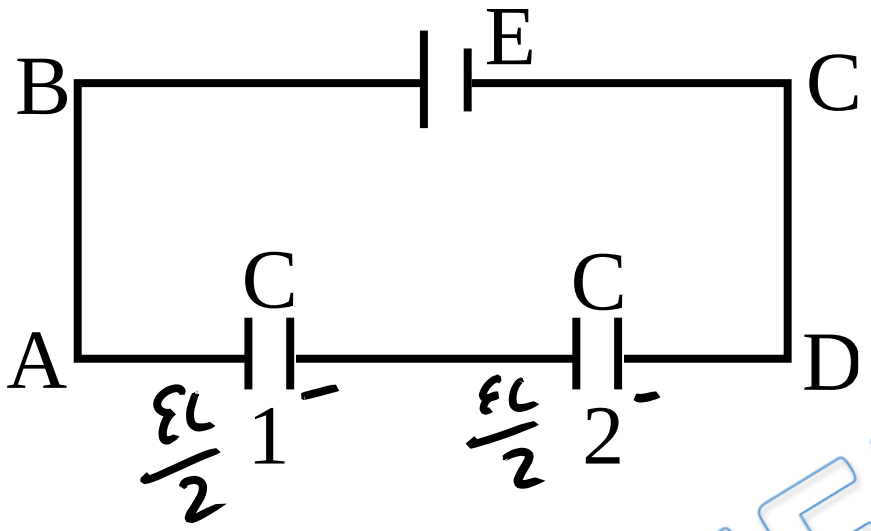
Potential of conductor $V=\frac{q-q/2}{4\pi\epsilon_0 \times 1}+\frac{q/2}{4\pi\epsilon_0 \times 2}$

$V=\frac{q}{2}(9\times10^9)(3/2)$

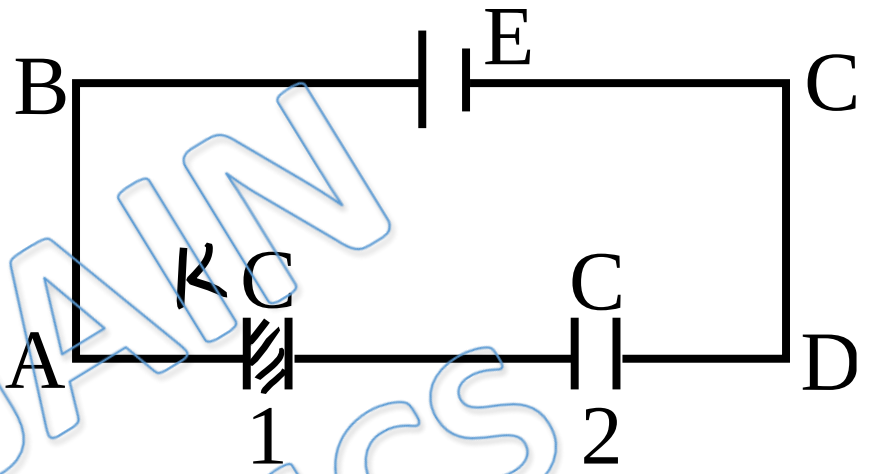
$C=\frac{q}{V}=\frac{4}{27}\,nF$

Ans(a)

12)



$\Rightarrow$



final effective capacitance $= \frac{KC \times C}{KC + C} = \frac{KC}{K+1}$

charge on each capacitor on inserting dielectric $= \frac{K\varepsilon C}{K+1}$

Charge supplied by cell " " " "

$= \frac{K\varepsilon C}{K+1} - \frac{\varepsilon C}{2} = \frac{\varepsilon C}{2}\left(\frac{K-1}{K+1}\right)$

Ans (d)

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