Physicsaholics

DPP – 4 (Capacitor)

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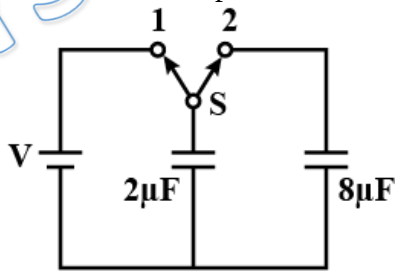
Q 1. Two capacitors of capacitances 1μF and 3μF are charged to the same voltages 5V. They are connected in parallel with oppositely charged plates connected together. Then
(a) Final common voltage will be 5 V
(b) Final common voltage will be 2 V
(c) Heat produced in the circuit will be zero
(d) Heat produced in the circuit will be 37.5μJ

Q 2. A capacitor of 5μF is charged to a potential of 100V. Now, this charged capacitor is connected to a battery of 100V with the positive terminal of the battery connected to the negative plate of the capacitor. For the given situation, mark the correct statement.
(a) The charge flowing through the 100V battery is 500μC
(b) The charge flowing through the 100V battery is 2000μC
(c) Work done by the battery is 0.1 J
(d) Work done on the battery is 0.1 J

Q 3. A 12pF capacitor is connected to a 50 V battery. How much of electrostatic energy is stored in the capacitor?
(a) 15×10^{-9} J (b) 5×10^{-10} J
(c) 1.5×10^{-10} J (d) 1×10^{-8} J

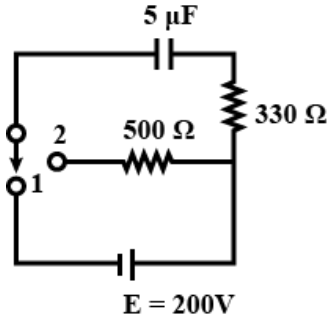
Q 4. A 2μF capacitor is charged as shown in figure. The percentage of its stored energy dissipated after the switch S is turned to position 2 is



(a) 0 % (b) 20 %
(c) 75 % (d) 80 %

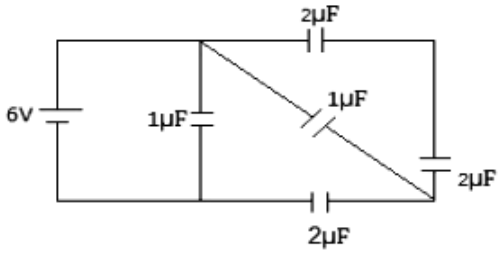
Q 5. A capacitor of capacitance 100μF is connected across a battery of emf 6.0V through a resistance of 20kΩ for 4.0s. The battery is then replaced by a thick wire. What will be the charge on the capacitor 4.0s after the battery is disconnected? (Given $e^{-2} = .15$)
(a) 76.5 μC (b) 30 μC
(c) 85 μC (d) 58 μC

Q 6. The amount of heat generated in 500Ω resistance, when the key is thrown over from contact 1 to 2, as shown in figure is?



(a) 40×10^{-3} J (b) 50×10^{-3} J
(c) 60×10^{-3} J (d) 30×10^{-3} J

Q 7. Find total energy stored in capacitors given in the circuit

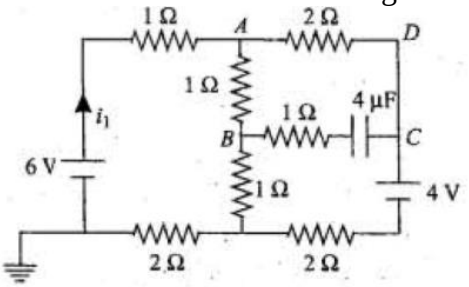


(a) 36×10^{-6} J (b) 3.6×10^{-7} J
(c) 45×10^{-5} J (d) 25×10^{-6} J

Q 8. The two parallel plates of a condenser have been connected to a battery of 300 V and the magnitude of charge collected at each plates is 1μC. The energy supplied by the battery is:
(a) 6×10^{-4} J (b) 3×10^{-4} J
(c) 1.5×10^{-4} J (d) 4.5×10^{-4} J

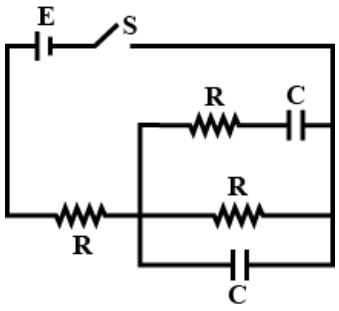
Q 9. A parallel-plate capacitor with the plate area $100cm^2$ and the separation between the plats 1.0cm is connected across a battery of emf 24 volts. Find the force of attraction between the plates.
(a) 2×10^{-6} N (b) 3.45×10^{-4} N
(c) 1.32×10^{-5} N (d) 2.57×10^{-7} N

Q 10. Consider the circuit shown in figure. The circuit is in steady state. The value of i_1 is:



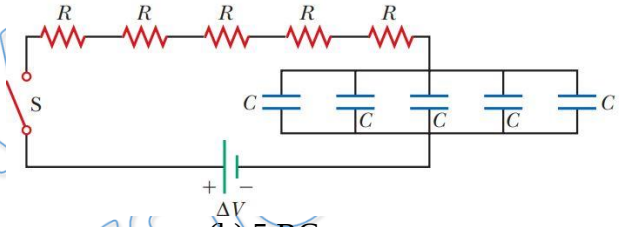
(a) $\frac{7}{9}$ A
(b) $\frac{14}{13}$ A
(c) $\frac{14}{3}$ A
(d) $\frac{13}{27}$ A

Q 11. In the given circuit, if the current through cell is I, immediately after closing the switch and will become I' long after closing the switch, then $\frac{I}{I'}$



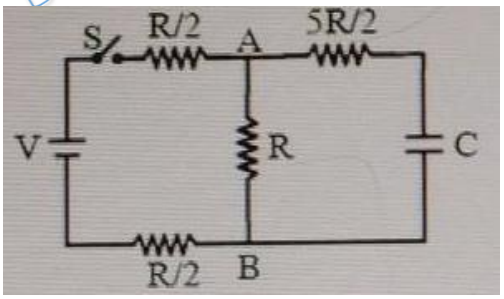
(a) 2
(b) $\frac{2}{3}$
(c) $\frac{3}{2}$
(d) 3

Q 12. What is the time constant of the circuit shown in Figure? Each of the five resistors has resistance R, and each of the five capacitors has capacitance C. The internal resistance of the battery is negligible.



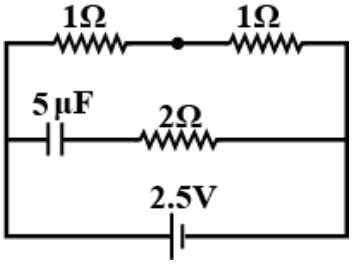
(a) RC
(b) 5 RC
(c) 10 RC
(d) 25 RC

Q 13. In the circuit shown in figure, the battery is an ideal one with emf V. The capacitor is initially unchanged. Switch S is closed at time t = 0. The final charge Q on the capacitor is:



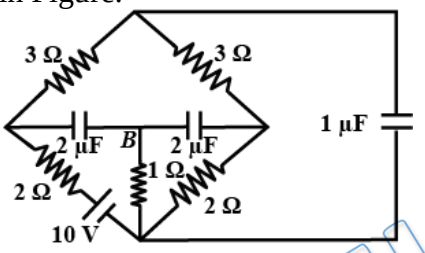
(a) $\frac{CV}{2}$
(b) $\frac{CV}{3}$
(c) CV
(d) $\frac{CV}{6}$

Q 14. A capacitor of capacitance 5μF is connected as shown in the figure. The internal resistance of the cell is 0.5Ω. The amount of charge on the capacitor plate is



(a) 0 μC (b) 5 μC
(c) 10 μC (d) 25 μC

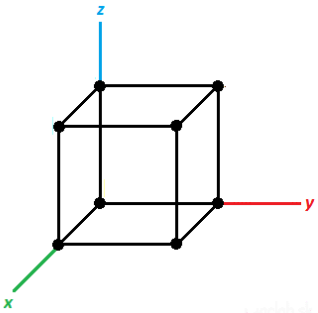
Q 15. The circuit shown in Figure is in steady state. Find the energy stored in the capacitors shown in Figure.



(a) 8 μJ (b) 80.5 μJ
(c) 35 μJ (d) 17.5 μJ

Q 16. What is the energy stored per unit volume in vacuum, where the intensity of electric field is 10^3 V/m? ($\varepsilon_0 = 8.85 \times 10^{-12} C^2/N - m^2$)
(a) 8.85×10^{-6} J/m^3 (b) 4.425×10^{-6} J/m^3
(c) 4.425×10^{-8} J/m^3 (d) 8.85×10^{-5} J/m^3

Q 17. Electric field in a region is found to be E = 3y ĵ. The total energy stored in electric field inside the cube shown will be



(a) $9a^5\varepsilon_0$ (b) $3a^5\varepsilon_0$
(c) $\frac{3}{2}a^5\varepsilon_0$ (d) zero

Q 18. Find out energy stored in the electric field of uniformly charged thin spherical shell of total charge Q and radius R.
(a) $\frac{kQ^2}{2R}$ (b) $\frac{kQ^2}{3R}$
(c) $\frac{3kQ^2}{2R}$ (d) $\frac{2kQ^2}{R}$

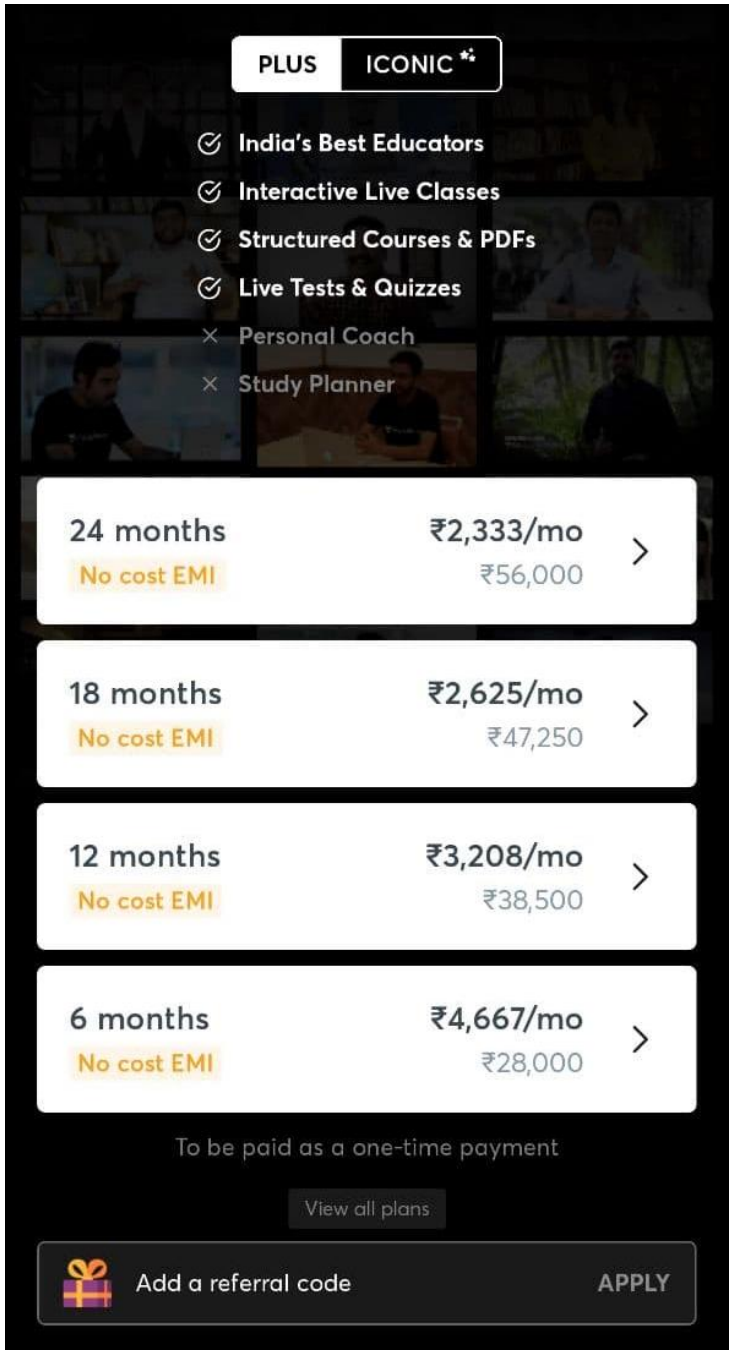
Q 19. A parallel plate capacitor has an electric field of 10^5 V/m between the plates. If the charge on the capacitor plate is 1μC, then force on each capacitor plate is-

(a) 0.1 N (b) 0.05 N

(c) 0.02 N (d) 0.01 N

Answer Key

Q.1 d	**Q.2 c**	**Q.3 a**	**Q.4 d**	**Q.5 a**
Q.6 c	**Q.7 a**	**Q.8 c**	**Q.9 d**	**Q.10 b**
Q.11 a	**Q.12 d**	**Q.13 a**	**Q.14 c**	**Q.15 b**
Q.16 b	**Q.17 c**	**Q.18 a**	**Q.19 b**	



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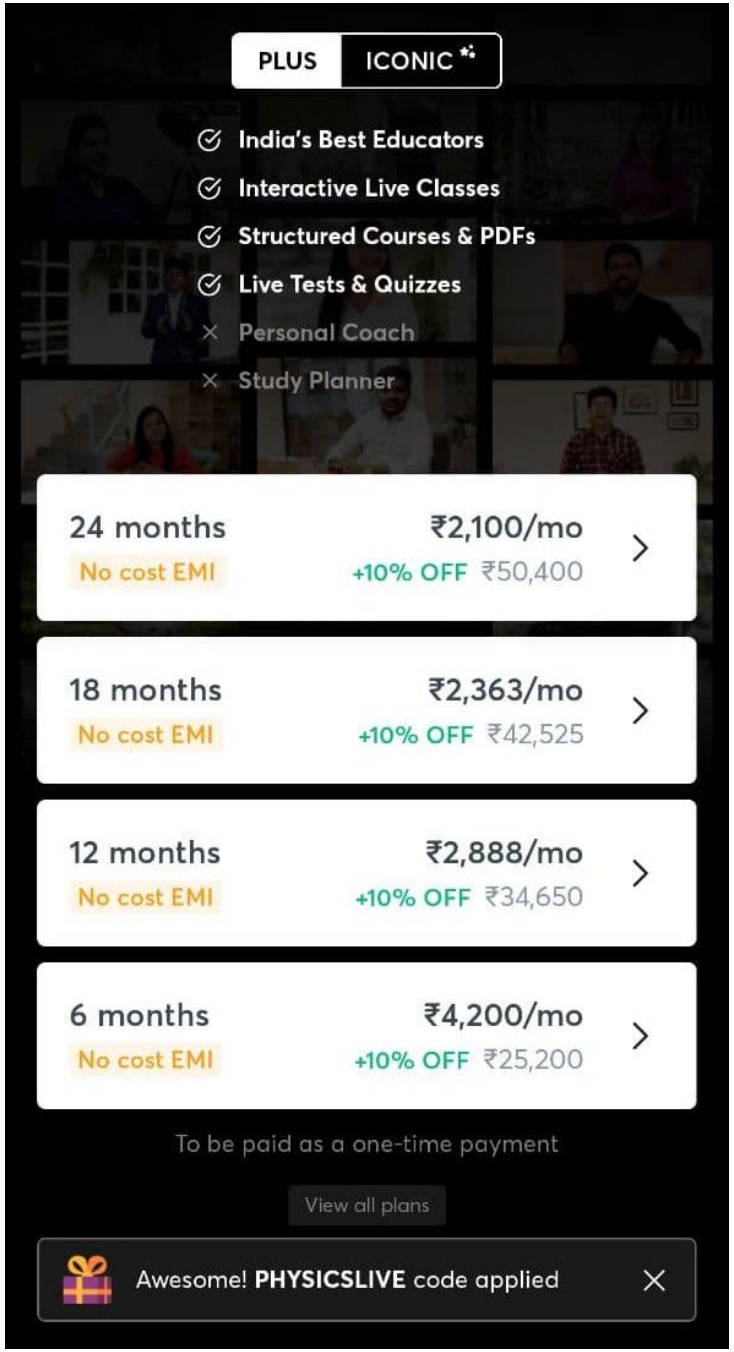
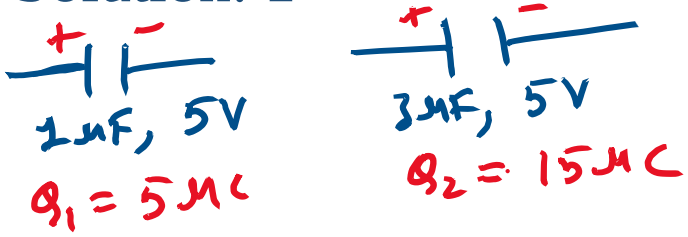


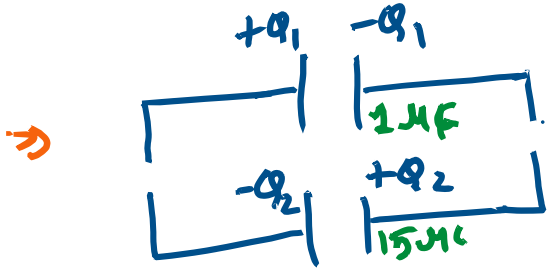
Written Solution

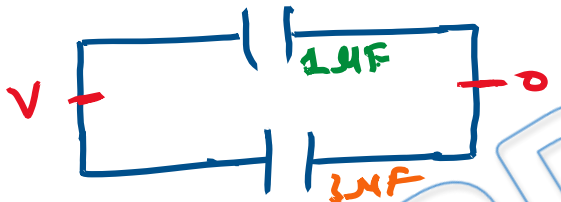
DPP 4 – Capacitor: Energy in Capacitor, R-C Circuit & Energy stored in Electric Field

By Physicsaholics Team

Solution: 1







$$V = \left|\frac{C_1V_1 - C_2V_2}{C_1 + C_2}\right|$$

$$V = \left|\frac{5 - 15}{4}\right|$$

$$V = 5/2 \text{ Volt}$$

$$U_i = \frac{q_1^2}{2C_1} + \frac{q_2^2}{2C_2} = \frac{5^2}{2\times1}\mu J + \frac{15^2}{2\times3}\mu J$$

$$U_i = \left(\frac{25}{2} + \frac{225}{6}\right)\mu J = \frac{300}{6}\mu J$$

$$U_i = 50\mu J$$

$$U_f = \frac{1}{2}C_{eq}V^2 = \frac{1}{2}(4\mu F)\left(\frac{5}{2}\right)^2 = \frac{25}{2}\mu J$$

$$U_f = 12.5 \ \mu J$$

$$H = U_i - U_f = 50\mu J - 12.5 \ \mu J$$

$$H = 37.5 \ \mu J$$

$$H = 37.5\ \mu J$$ Ans

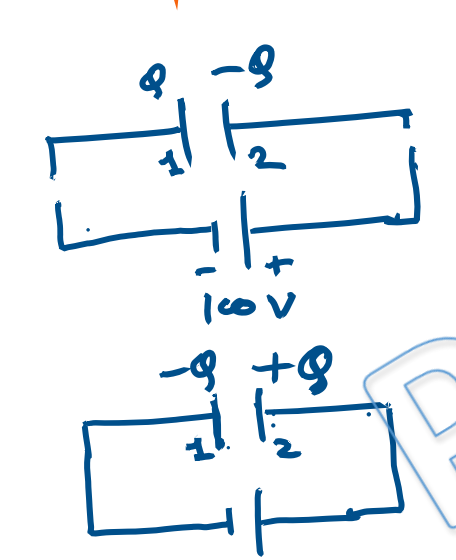
Ans. d

Solution: 2

$C = 5\mu F$

$q = CV = 5\mu F \times 100$

$q = 500\ \mu C$



Charge flown $= (q_1)_f - (q_1)_i$

$= -q - (q)$

$= -2q$

Charge flown

$q = 2q$

$= 2 \times 500\ \mu C$

$\boxed{q = 1000\ \mu C}$

Work done by battery

$= q\Delta V$

$= (1000\ \mu C)(100\ V)$

$= 10,0000 \times 10^{-6}\ J$

$\boxed{W = 0.1\ J}$ Ans

Ans. c

Solution: 3

$$E = \frac{1}{2} CV^2$$

$$= \frac{1}{2} \times (12\,pF) \times (50)^2$$

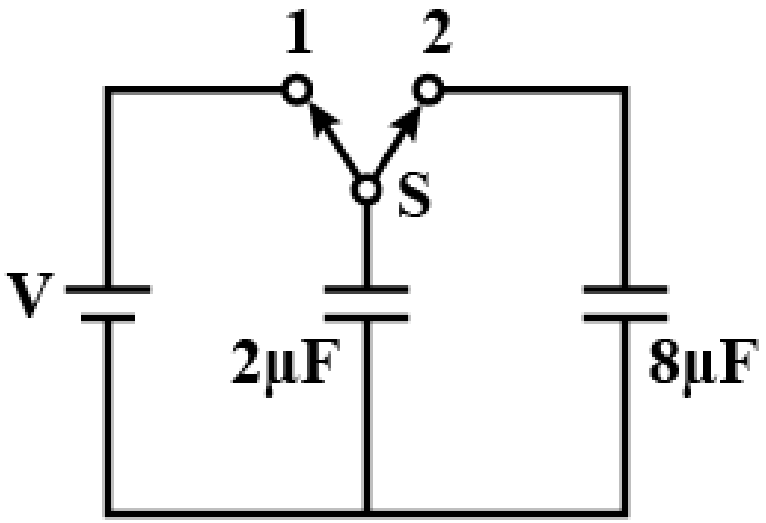
$$= 6 \times 2500 \times 10^{-12}\ J$$

$$= 150 \times 10^{-10}\ J$$

$$\boxed{E = 15 \times 10^{-9}\ J}$$ Ans

Ans. a

Solution: 4



when connected with '1'

$U_i = \frac{1}{2} C V^2$

$U_i = \frac{1}{2}(2\mu F) V^2 = (1\mu F) V^2$

$q_i = C_1 V_1 = (2\mu F) V$

When, connected to '2'

Common Potential

$V_c = \frac{C_1 V_1}{C_1 + C_2} = \frac{(2\mu F) V}{(2+8)\mu F}$

$V_c = \frac{V}{5}$

final energy

$U_f = \frac{1}{2} C_{eq} V^2 = \frac{1}{2}(10\mu F) \times \left(\frac{V}{5}\right)^2$

$U_f = \frac{1}{2}(10\mu F)\frac{V^2}{25} = (1\mu F)\frac{V^2}{5}$

it $U_i = U = (1\mu F) V^2$

then; $U_f = \frac{V^2}{5} = \frac{U}{5}$

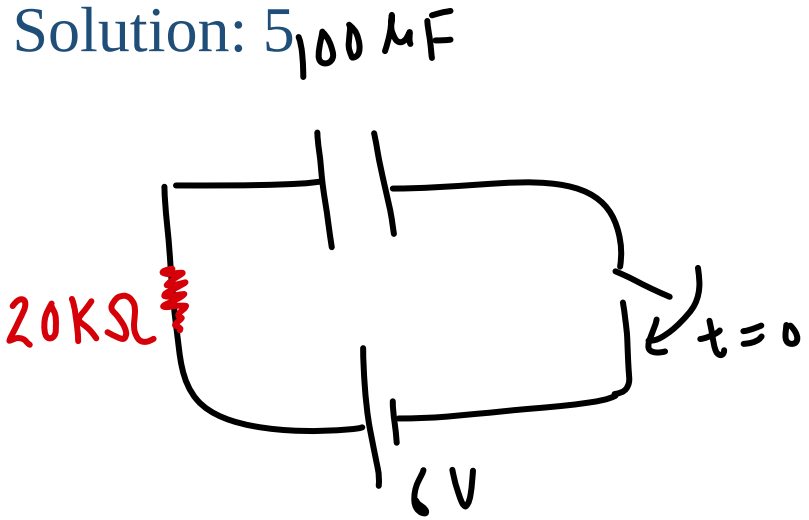
$\frac{\Delta U}{U}\% = \frac{\frac{U}{5} - U}{U} \times 100 = \frac{-4U}{\frac{5}{U}} \times 100$

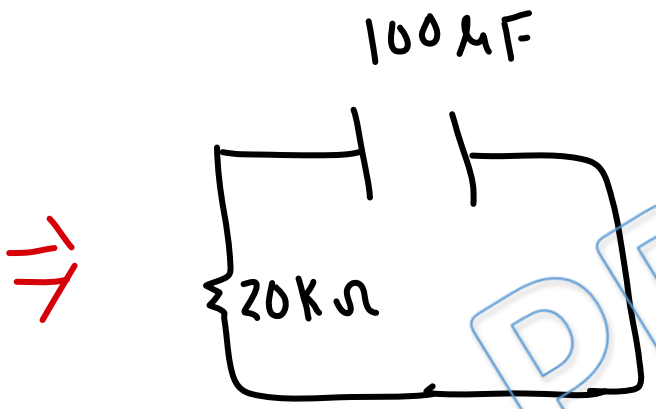
$\boxed{\frac{\Delta U}{U}\% = -80\%}$

80% decreased Ans

Ans. d

Solution: 5





⇒ Discharging R-C Circuit.

Time Constant $\tau = RC = 20K \times 100\mu = 2$ Sec

Charge on Capacitor after 4 Sec

$$q_1 = \varepsilon C\left(1 - e^{-t/\tau}\right) = 6 \times 100\mu\left(1 - e^{-4/2}\right)$$

$$= 600\mu \times \left(1 - \frac{1}{e^2}\right) = 600\mu(1 - .15)$$

$$= 600 \times .85\,\mu C = 510\,\mu C$$

Charge on Capacitor after 4 Sec in discharging Circuit →

$$q_2 = q_1 e^{-t/\tau} = 510 e^{-4/2} = 510 e^{-2}\,\mu C$$

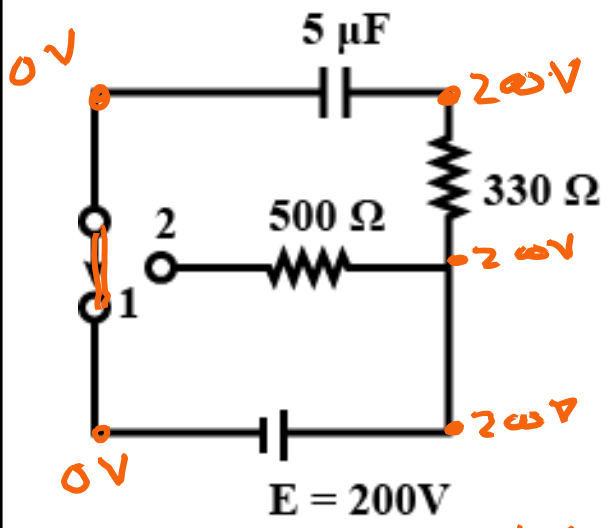
$$= 510 \times .15\,\mu C = 76.50\,\mu C$$

Ans(a)

Ans. a

Solution: 6

when key is connected to '1'



in steady state

Energy in capacitor

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

$= \frac{1}{2} \times (5 \times 10^{-6})(200)^2$

$= \frac{1}{2} \times (5 \times 10^{-6}) \times 4 \times 10^4$

$U = 5 \times 10^{-6} \times 2 \times 10^4$

$\boxed{U = 0.1\,J}$

when key is switched to '2'

whole Energy will dissipate in heat Energy through resistors.

$H = U$

So, $\boxed{H = 0.1\,J}$

Let Heat dissipated in 500Ω = H_1 & in 330Ω = H_2

$\therefore H_1 + H_2 = 0.1\,J.$

& $\because I$ = Same in Both

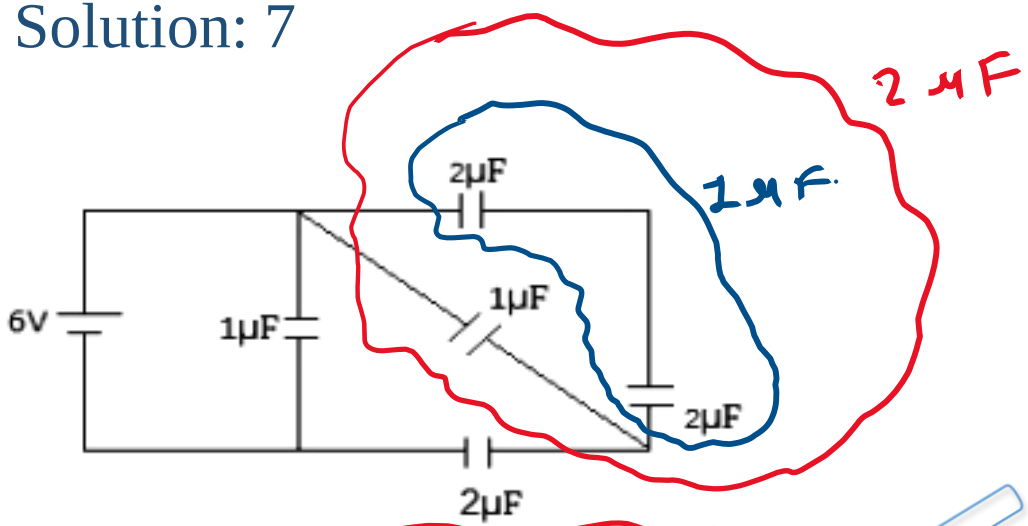
So, $H = I^2Rt \Rightarrow H \propto R \Rightarrow \frac{H_1}{H_2} = \frac{500}{330} = \frac{50}{33}$

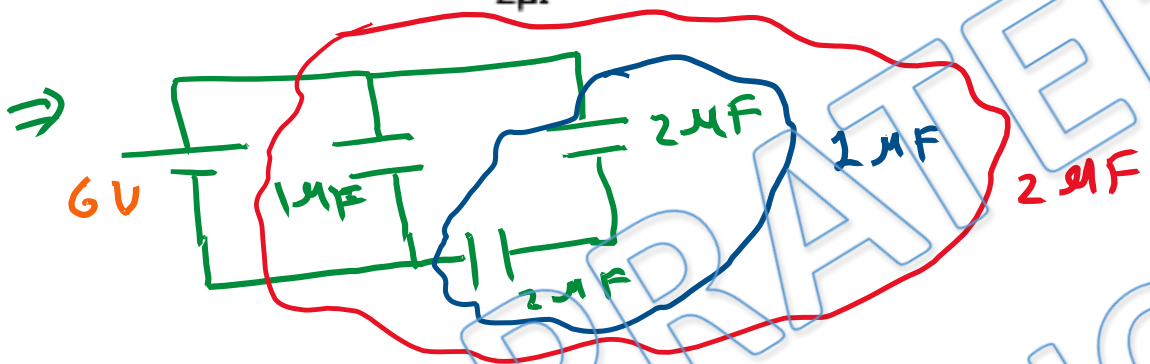
So, $H_1 = \frac{50}{83} \times 0.1 = 0.06\,J$

$\boxed{H_1 = 60 \times 10^{-3}\,J}$ Ans

Ans. c

Solution: 7





$C_{eq} = 2\mu F$

$U = \frac{1}{2} C_{eq} V^2 = \frac{1}{2}(2\mu F)(6)^2$

$\boxed{U = 36\mu J}$ Ans.

Ans. a

Solution: 8

$U = q \cdot V$

$= (1\mu C) \times (300)$

$U = 0.3\ mJ$

$U = 3 \times 10^{-4}\ J$ Ans

Ans. c

Solution: 9

$A = 100\ cm^2$

$d = 1\ cm$

$V = 24\ Volts$

$$C = \frac{\epsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 100 \times 10^{-4}}{1 \times 10^{-2}}$$

$$C = 8.85 \times 10^{-12}\ F$$

$$C = 8.85\ pF$$

$$Q = CV$$

$$Q = 8.85 \times 10^{-12} \times 24$$

$$Q = 212.4 \times 10^{-12}\ C$$

$$F = qE$$

$$F = q\left[\frac{\sigma}{2\epsilon_0}\right]$$

$$F = q\left(\frac{q/A}{2\epsilon_0}\right) = q\left(\frac{q}{2A\epsilon_0}\right)$$

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

$$F = \frac{(212.4)^2 \times (10^{-12})^2}{2 \times 100 \times 10^{-4} \times 8.85 \times 10^{-12}}$$

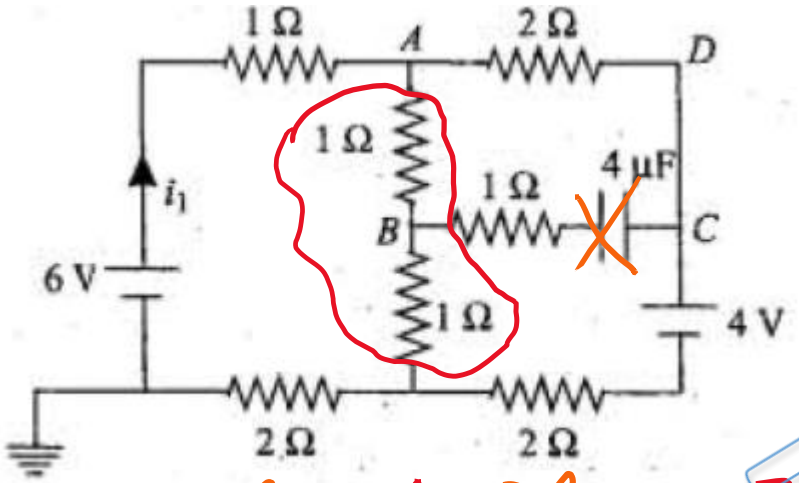
$$F = 2548.8 \times 10^{-10}$$

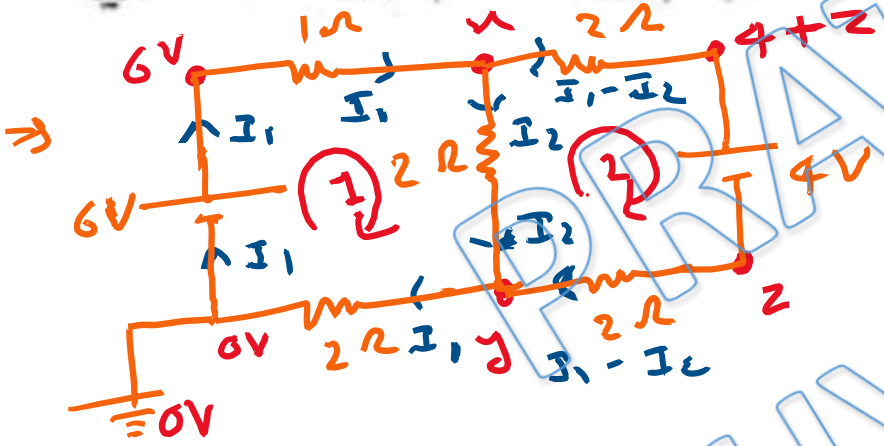
$$\boxed{F = 2.5 \times 10^{-7}\ N}$$ Ans

Ans. d

Solution: 10

in steady state :- Capacitors will behave like insulators.





Loop-1

$6 - I_1(1) - 2(I_2) - 2I_1 = 0$

$3I_1 + 2I_2 - 6 = 0$ —①

Loop-2

$-2(I_1-I_2) - 4 - 2(I_1-I_2) + 2I_2 = 0$

$-4I_1 + 6I_2 - 4 = 0$

$-2I_1 + 3I_2 - 2 = 0$ —②

$(3\times①) + (-2\times②) \Rightarrow$

$9I_1 + 6I_2 - 18 = 0$

$4I_1 - 6I_2 + 4 = 0$

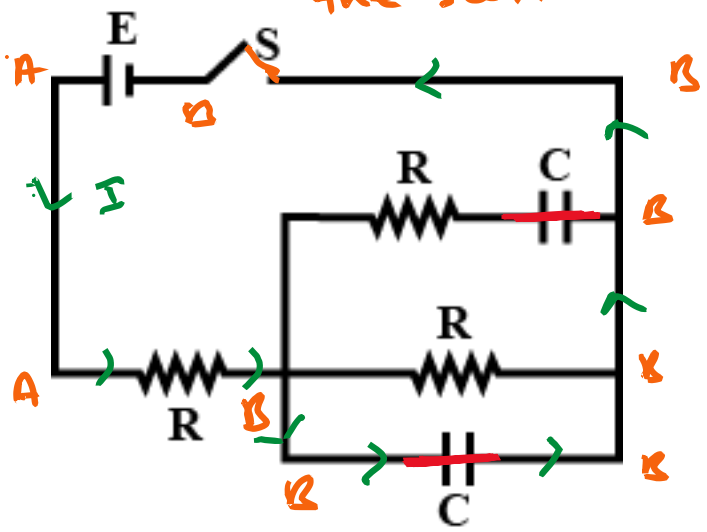
$13I_1 - 14 = 0$

$\boxed{I_1 = \frac{14}{13}\ \text{Amp}}$ Ans

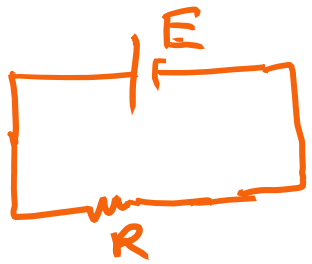
Ans. b

Solution: 11

Immediately after closing the switch

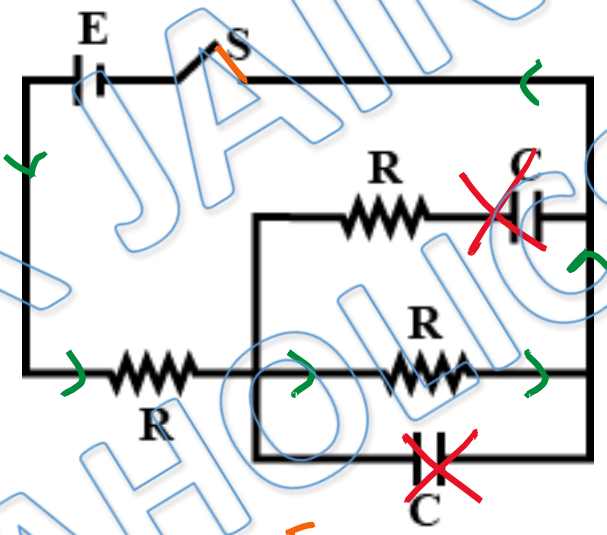


$\Rightarrow$

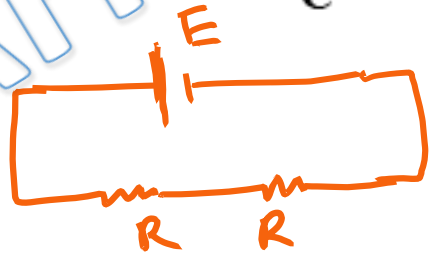


$$I = \frac{E}{R}$$

Long time after closing the switch



$\Rightarrow$



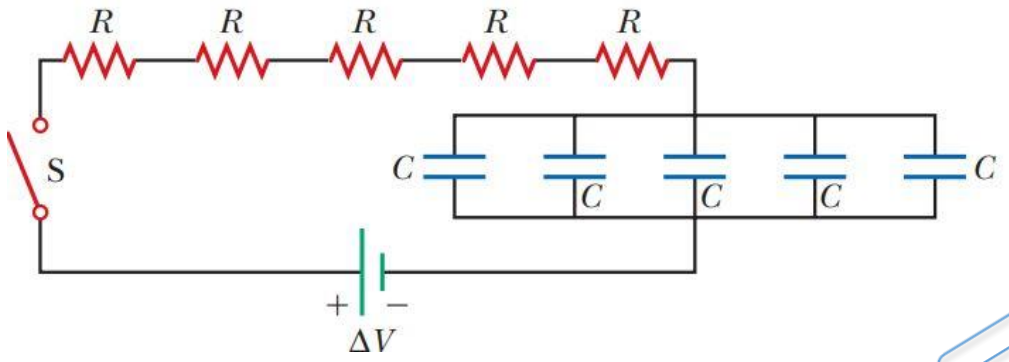
$$I' = \frac{E}{2R}$$

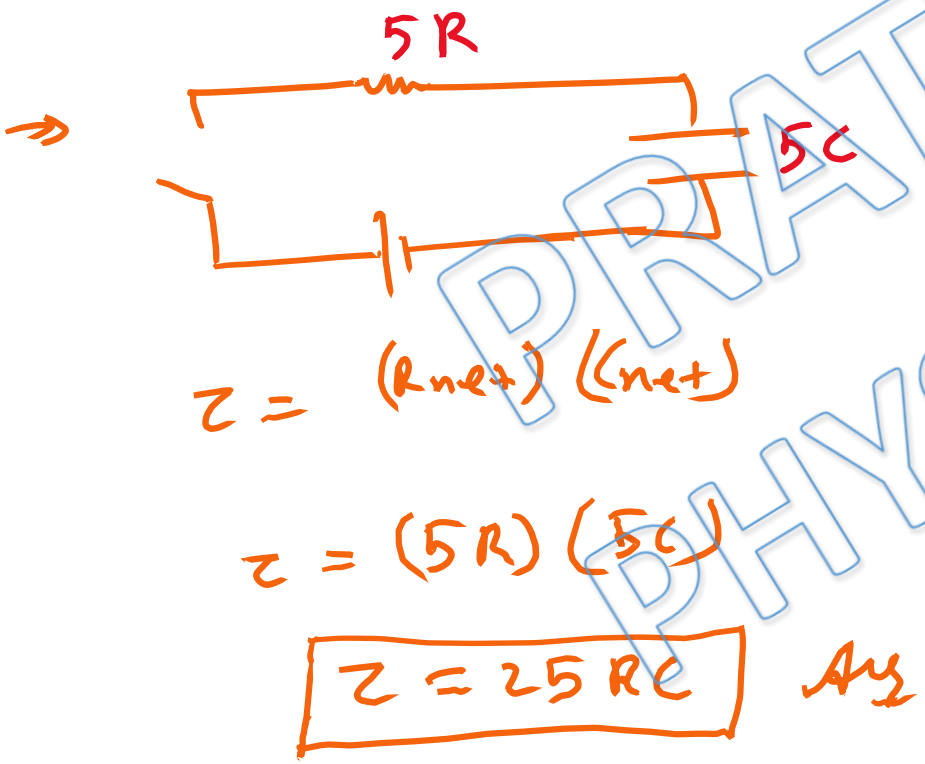
$$\Rightarrow \frac{I}{I'} = \frac{E/R}{E/2R}$$

$$\frac{I}{I'} = 2$$

Ans. a

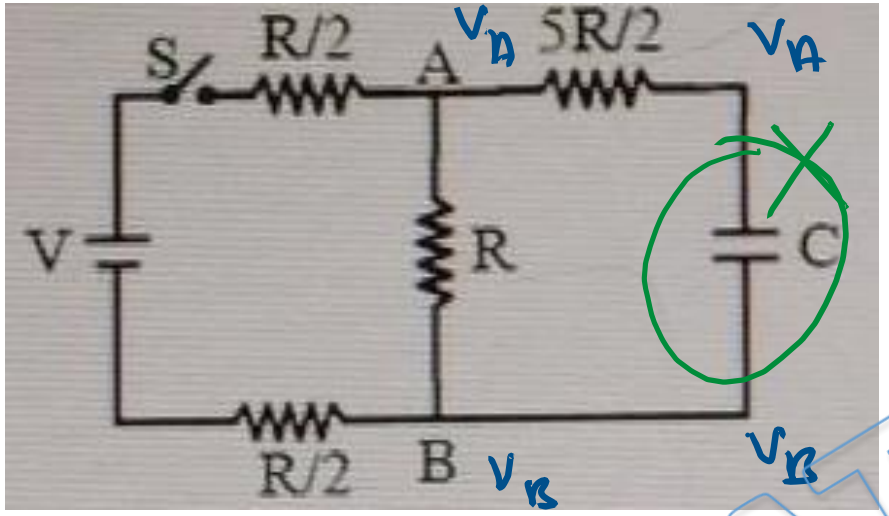
Solution: 12





Ans. d

Solution: 13



$V_{AB} = I \cdot R_{AB} = I \times R$

$V_{AB} = \frac{V}{2R} \times R$

$\boxed{V_{AB} = \frac{V}{2}}$

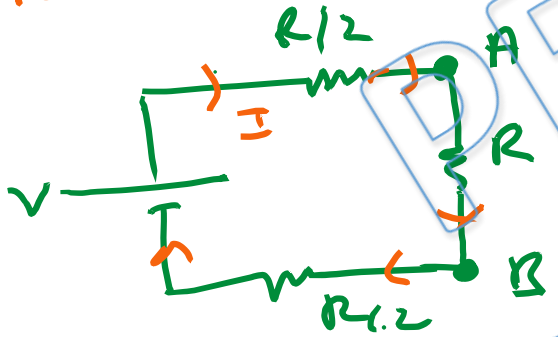
Potential across 'C' = V_{AB}

So, $Q = CV_{AB}$

$Q = C\frac{V}{2}$

$\boxed{Q = \frac{CV}{2}}$ Ans

$\Rightarrow$

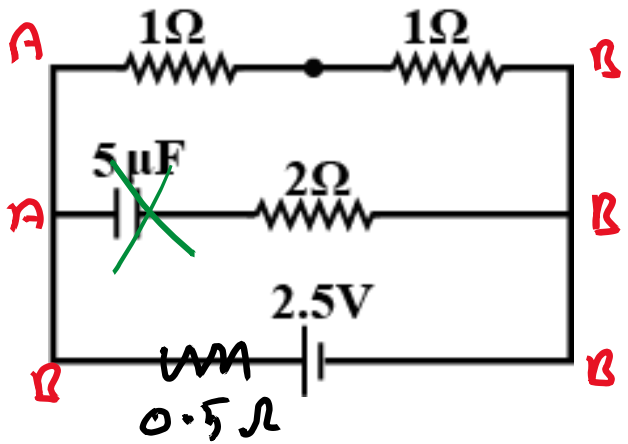


$\boxed{I = \frac{V}{2R}}$

Ans. a

Solution: 14

In steady state



$V_{AB} = I(1+1) = 2I$

$V_{AB} = 1 \times 2 = 2$ Volt

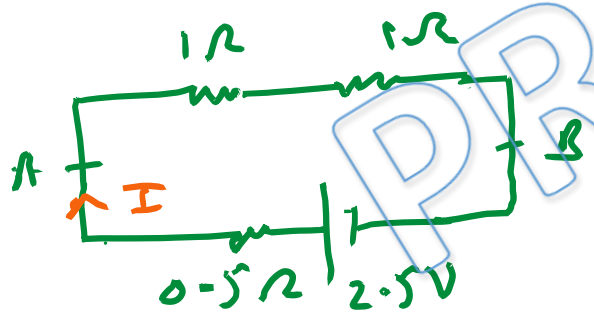
$Q = CV$

$Q = 5\mu F \times 2$ Volt

$\boxed{Q = 10\mu C}$ Ans

Potential across 'C' = V_{AB}

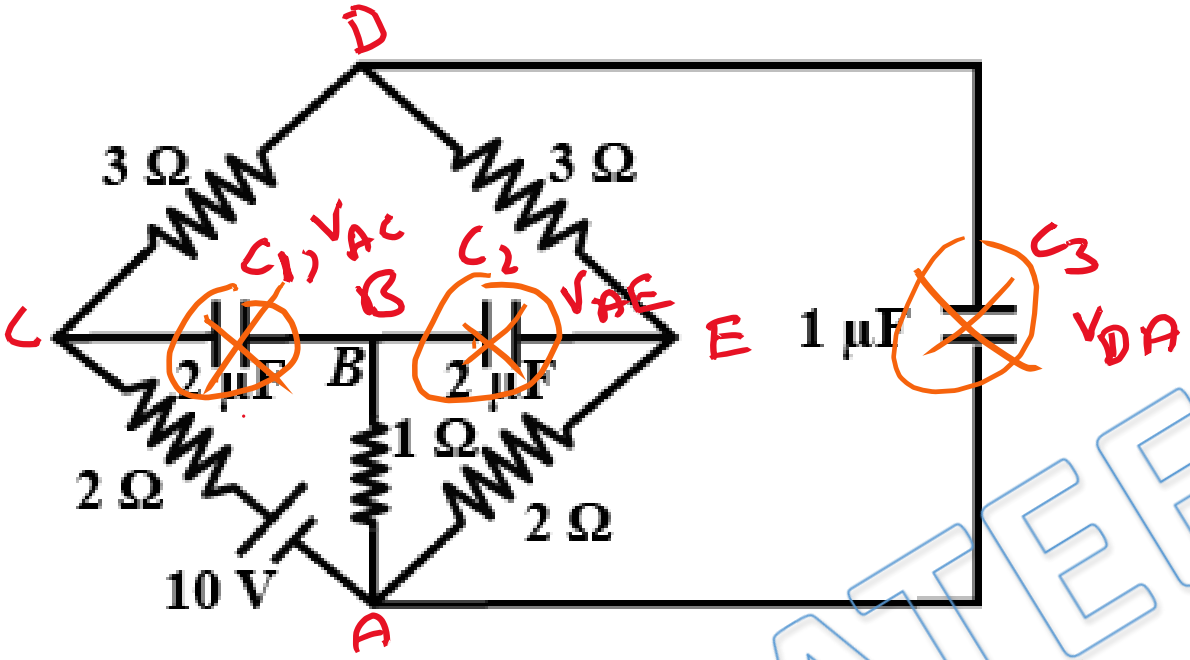
$\Rightarrow$



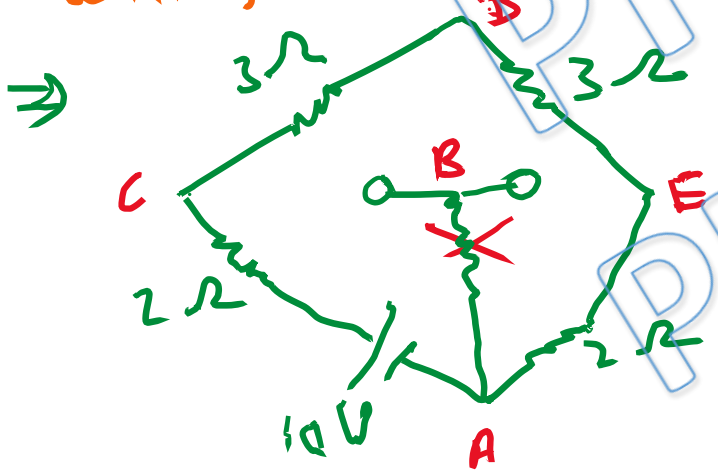
$I = \frac{2.5}{2.5} = 1$ Amp

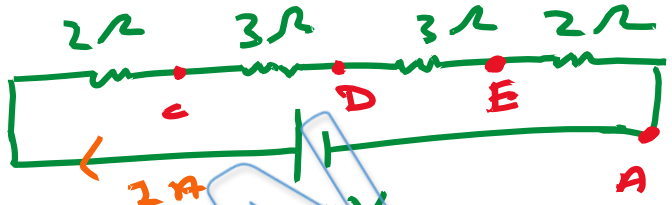
Ans. c

Solution: 15



in steady state; no current will flow through capacitors





$I = \frac{V}{R_{net}}$

$I = \frac{10}{10}$

$\boxed{I = 1\ Amp}$

$V_{AD} = 1 \times 5 = 5V$, $V_{DE} = 1 \times 3 = 3V$

$V_{EA} = 1 \times 2 = 2V$, $V_{CA} = 1 \times 8 = 8V$

So, $U = \frac{1}{2}(2\mu F)(8)^2 + \frac{1}{2}(2\mu F)(2)^2 + \frac{1}{2}(1\mu F)(5)^2$

$= 64\mu J + 4\mu J + 12.5\mu J$

$\boxed{U = 80.5\mu J}$ Ans

Ans. b

Solution: 16

$$\frac{U}{V} = \frac{1}{2}\epsilon_0 E^2$$

$$= \frac{1}{2} \times 8.85 \times 10^{-12} \times (10^3)^2$$

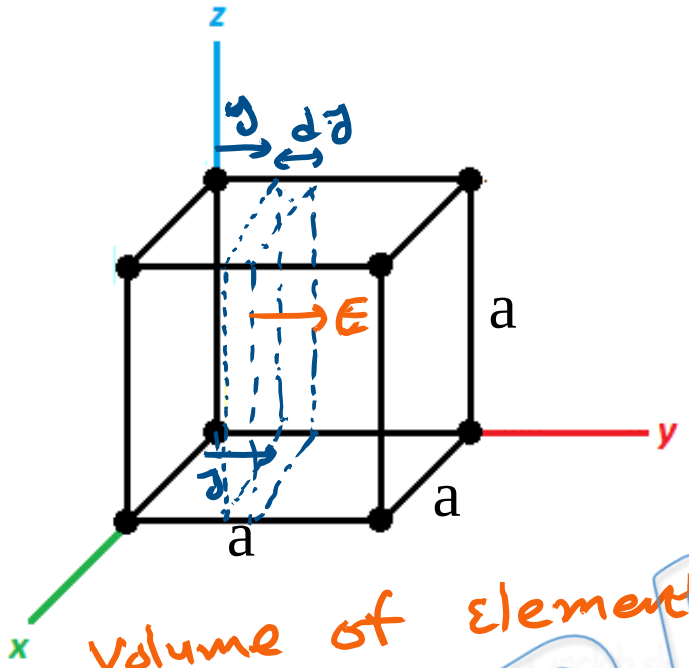
$$= 4.425 \times 10^{-12} \times 10^6$$

$$= 4.425 \times 10^{-6}$$

$$\boxed{\frac{U}{V} = 4.425 \times 10^{-6}\ J/m^3} \quad \text{Ans.}$$

Ans. b

Solution: 17



Volume of element = $A \cdot dy$
$= (a^2 dy)$

$\frac{dU}{dV} = \frac{1}{2}\epsilon_0 E^2$

$\frac{dU}{dV} = \frac{1}{2}\epsilon_0 (Ky)^2 = \frac{K}{2}\epsilon_0 y^2$

$dU = \frac{K}{2}\epsilon_0 y^2 \, dV = \frac{K}{2}\epsilon_0 y^2 (a^2 dy)$

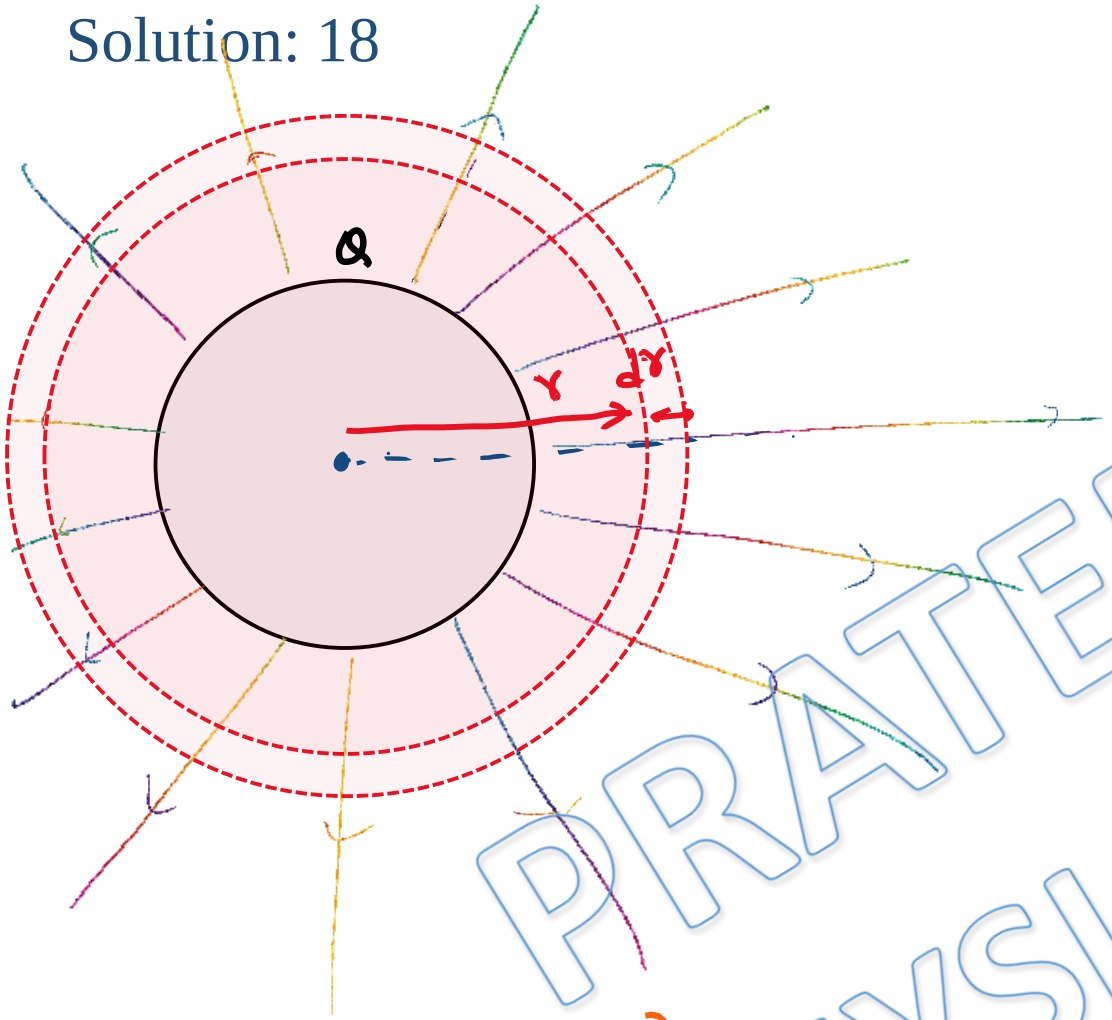
$\int_0^U dU = \frac{K}{2} a^2 \epsilon_0 \int_0^a y^2 dy$

$U = \frac{K}{2} a^2 \epsilon_0 \left[\frac{y^3}{3}\right]_0^a = \frac{K}{2} a^2 \epsilon_0 \left[\frac{a^3}{3}\right]$

$\boxed{U = \frac{K}{6} a^5 \epsilon_0}$ Ans

Ans. c

Solution: 18



$$\frac{dU}{4\pi r^2 . dr} = \frac{1}{2}\epsilon_0 \left(\frac{kQ}{r^2}\right)^2$$

$$dU = \frac{\epsilon_0 k^2 Q^2}{2 r^4}\left[4\pi r^2 . dr\right]$$

$$\int_0^U dU = \frac{4\pi\epsilon_0 k^2 Q^2}{2}\int_R^\infty \frac{1}{r^2} dr$$

$$U = \frac{k^2 Q^2}{2\left(\frac{1}{4\pi\epsilon_0}\right)}\left[\frac{-1}{r}\right]_R^\infty$$

$$U = \frac{k^2 Q^2}{2k}\left[\frac{-1}{\infty} - \left(\frac{-1}{R}\right)\right]$$

$$U = \frac{kQ^2}{2}\left[0 + \frac{1}{R}\right]$$

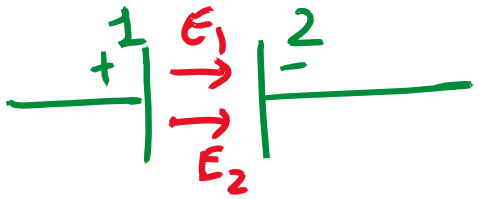
$$\boxed{U = \frac{kQ^2}{2R}}$$ Ans.

$$\frac{dU}{dV} = \frac{1}{2}\epsilon E^2$$

$$E = \frac{kQ}{r^2}$$

Ans. a

Solution: 19



$F = qE$

Force on Plate '1' due to plate '2'

$F = q_1 E_2$

$F = (1\mu C)(5 \times 10^4)$

$F = 1 \times 10^{-6} \times 5 \times 10^4$

$F = 5 \times 10^{-2}$

$\boxed{F = 0.05\ N}$ Ans.

$E_1 = E_2 = E$

$E_1 + E_2 = 10^5$

$2E = 10^5$

$E = 5 \times 10^4\ V/m$

Ans. b

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