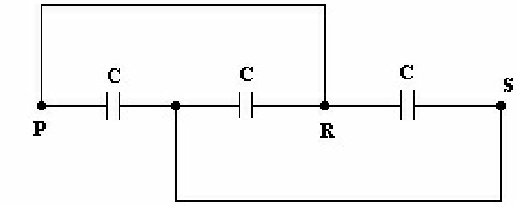
CBSE Test Paper-05

Class - 12 Physics (Electrostatic Potential and Capacitance)

1. If the charge on a capacitor is increased by 2 coulomb, the energy stored in it increases by 21%. The original charge on the capacitor (in coulomb) is
   a. 30
   b. 20
   c. 40
   d. 40
   e. 10
2. A parallel plate capacitor of capacitance C is connected to a battery and is charged to a potential difference V. Another capacitor of capacitance 2C is similarly charged to a potential difference 2V. The charging battery is then disconnected and 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 the other. The final energy of the configuration is
   a. $\frac{25}{6}\mathrm{CV}^2$
   b. $\frac{3}{2}\mathrm{CV}^2$
   c. $\frac{9}{2}\mathrm{CV}^2$
   d. zero
3. when two capacitors are put in series, the equivalent capacitance is
   a. the product of the capacitances
   b. the reciprocal of the capacitances
   c. smaller than both capacitances
   d. the sum of the capacitances
4. For a parallel plate capacitor _________ possible potential difference between the capacitor plates
   a. dielectric decreases the minimum
   b. dielectric increases the minimum
   c. dielectric increases the maximum
   d. dielectric decreases the maximum
5. Three capacitors, each of capacitance C = 3 mF, are connected as shown in the figure.

The equivalent capacitance between points P and S is



a. 3 μF
b. 9 μF
c. 1 μF
d. 6 μF

6. We know that electric field is discontinuous across the surface of a charged conductor. Is electric potential also discontinuous there?

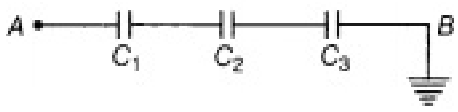
7. Name the physical quantity whose SI unit is JC^{-1}. Is it a scalar or a vector quantity?

8. Does the electric potential increase or decrease along the electric line of force?

9. Do electrons tend to go to regions of low potential or high potential?

10. What is the work done by the field of a nucleus in a complete circular orbit of the electron? What if the orbit is elliptical?

11. Calculate the potential difference and the energy stored in the capacitor C_2 in the circuit shown in the figure. Given potential at *A* is 90 V, C_1 = 20 μF, C_2 = 30 μF and C_3 = 15μF.



12. A cube of side b has a charge q at each of its vertices. Determine the potential and electric field due to these charges array at the centre of the cube.

13. A cylindrical capacitor has two co-axial cylinders of length 15 cm and radii 1.5 cm and 1.4 cm. The outer cylinder in earthed and the inner cylinder is given a charge of $3.5\mu C$. Determine the capacitance of the system and the potential of the inner cylinder. Neglect end effects (i.e. bending of field lines at the ends).

14. A capacitor of unknown capacitance is connected across a battery of V volt. The charge stored in it is 360μC. When potential across the capacitor is reduced by 120 V, the charge stored in it becomes 120 μC. Calculate (i) the potential V and the unknown capacitance C. (ii) what will be the charge stored in the capacitor, if the voltage applied had increased by 120 V?

15. An electrical technician requires a capacitance of $2\mu F$ in a circuit across a potential difference of 1kV. A large number of $1\mu F$ capacitors are available to him each of which can withstand a potential difference of not more than 400 V. Suggest a possible arrangement that requires the minimum number of capacitors.

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Answers

1. b. 20

   Explanation: The initial energy of the capacitor of capacitance C and charge Q1 is $U_1 = \frac{Q_1^2}{2C}$.

   When the charge increases to Q_2 the energy of the capacitor $\frac{U_2 - U_1}{U_1} = \frac{Q_2^2 - Q_1^2}{Q_1^2}$

   Given percentage increase of energy $\frac{U_2 - U_1}{U_1} = 0.21$

   $\therefore \frac{Q_2^2 - Q_1^2}{Q_1^2} = \frac{Q_2^2}{Q_1^2} - 1$

   $\Rightarrow 0.21 = \frac{Q_2^2}{Q_1^2} - 1$

   $\Rightarrow \quad 1.21 = \frac{Q_2^2}{Q_1^2}$

   $= \frac{Q_2}{Q_1} = 1.1$

   But $Q_2 - Q_1 = 2; Q_2 = 1.1Q_1$

   Solving Q_1 = 20C

2. b. $\frac{3}{2}\mathrm{CV}^2$

   Explanation: The charges Q_1 and Q_2 on the two capacitors Q_1 = CV; Q_2 = (2C)(2V)= 4CV.

   The capacitors are connected in parallel in such a way that the positive plate of one is connected to the negative plate of the other.

   The common potential $V = \frac{Q_2 - Q_1}{C + 2C} = \frac{4CV - CV}{3C} = V$.

   The final energy $U_f = \frac{1}{2}CV^2 + \frac{1}{2}(2C)V^2 = \frac{3}{2}CV^2$

3. c. smaller than both capacitances

   Explanation: When two capacitors C_1 and C_2 are connected in series, the reciprocal of the equivalent capacitance in series is equal to the sum of the reciprocals of the two individual capacitances.

   $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2};$

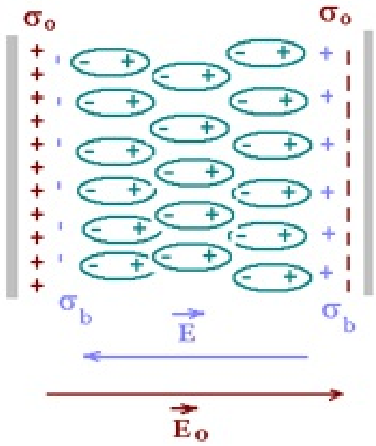
   $C_2 = \frac{C_1 C_2}{C_1 + C_2};$

$C_s < C_1$ and $C_s < C_2$

Thus equivalent capacitance will be less than the individual capacitances.

4. d. dielectric decreases the maximum

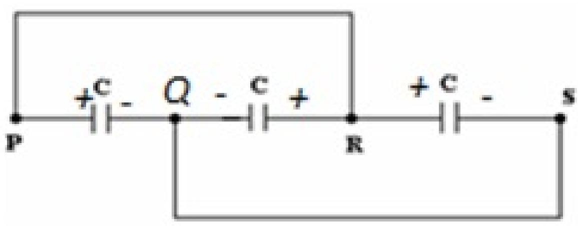
Explanation: When a dielectric is introduced between two charged plates of a capacitor having a charge Q and maintained at a potential difference of V, a reverse electric field is set up inside the dielectric due to dielectric polarization.



This reduces the electric field in between the plates. The potential is also reduced. Maximum potential is dependent on the charge on the plates. As the charge remains constant, the presence of the dielectric decreases the maximum potential between the plates.

5. b. 9 μF

Explanation: If P is at positive potential, then Q is at negative potential and R is at positive potential. The system therefore reduces to 3 capacitors in parallel. C= 9μF



6. No, since electric potential is a scalar quantity, it is continuous everywhere.

7. JC^{-1} is the SI unit of electrostatic potential or electrostatic potential difference.

It is a scalar quantity.

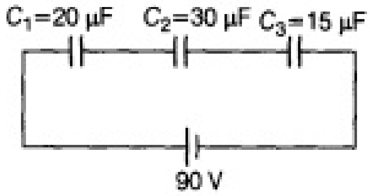
8. It decreases

9. Electrons, being negatively charged, tend to go to regions of high potential. This reduces their potential energy.

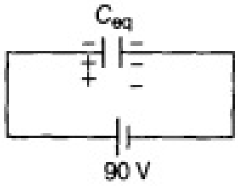
10. Whatsoever be the shape of the orbit work done is always zero because electron will be in the same energy state after it completes an orbit.

11. For a series combination of three capacitors C_1, C_2 and C_3, the equivalent capacitance C_{eq} will be

$$\frac{1}{C_{ca}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \Rightarrow \frac{1}{C_{eq}} = \frac{1}{20} + \frac{1}{30} + \frac{1}{15}$$



$$\Rightarrow \frac{1}{C_{\text{eq}}} = \frac{3+2+4}{60} \Rightarrow C_{\text{eq}} = \frac{60}{9}\mu\text{F} = \frac{20}{3}\mu\text{F}$$



Total charge of the system of three capacitors,

$$Q = C_{\text{eq}}V = \frac{20}{3} \times 10^{-6} \times 90$$
$$\Rightarrow Q = 600\mu C$$

Charge on each capacitor will remain same as they are in series with the battery.

Now, potential drop across the capacitor C_2,

$$V_2 = \frac{Q}{C_2} = \frac{600\times10^{-6}}{30\times10^{-6}} = 20\text{V}$$

Hence stored electrical potential energy U of capacitor C_2 is $U_2 = \frac{1}{2}C_2V_2^2$

$$U_2 = \frac{1}{2} \times 30 \times 10^{-6} \times (20)^2 = 6 \times 10^{-3}\text{J}$$

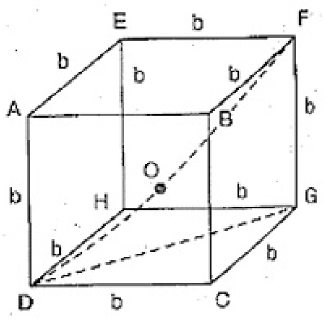
12. Diagonal DF of cube,

$$DF = \sqrt{b^2 + b^2 + b^2}$$

DF$= b\sqrt{3}$

Thus, $DO = \frac{DF}{2} = \frac{\sqrt{3}}{2}b$

Due to one charge q the potential at the centre O is given by



$$V=\frac{1}{4\pi\varepsilon_0}\frac{q}{r}=\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{\frac{\sqrt{3}b}{2}}\right)$$

Due to eight charges the total potential at the centre O is given as

$$V=8\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{\frac{\sqrt{3}}{2}b}\right)=\frac{4q}{\sqrt{3}\pi\varepsilon_0 b}$$

Remark : Due to two opposite corners D and F electric field intensity at the centre 'O' are equal in magnitude and opposite in direction. Therefore, they cancel out each other. Similarly, all other intensities cancel out each other and the total electric field at centre is zero.

13. Given, $q=3.5\mu C=3.5\times10^{-6}C$

a = 1.4 cm $=1.4\times10^{-2}m$

b = 1.5 cm $=1.5\times10^{-2}m$

l = 15 cm $=15\times10^{-2}m$, $C=\frac{2\pi\varepsilon_0 l}{2.303\log_{10}(b/a)}$

$$=\frac{2\times\pi\times8.854\times10^{-12}\times15\times10^{-2}}{2.303log_{10}\frac{1.5\times10^{-2}}{1.4\times10^{-2}}}$$

$$C=1.21\times10^{-10}F$$

The potential of inner cylinder will be equal to the potential difference between inner and outer cylinder as outer cylinder is earthed.

Hence, potential of inner cylinder

$$V=\frac{q}{C}=\frac{3.5\times10^{-6}}{1.21\times10^{-10}}$$

14. i. We have initial voltage, V_1 =V volt and charge stored, Q_1= 360μC(given in the question)

   We know that, $Q_1=CV_1$....(i)

   Now changed potential, V_2 = V - 120

   At that condition, stored charge Q_2 = 120μC

   Again applying formula, $Q_2=CV_2$ ...(ii)

By dividing Eq. (i) by Eq. (ii), we get

$\frac{Q_1}{Q_2} = \frac{CV_1}{CV_2} \Rightarrow \frac{360}{120} = \frac{V}{V-120}$

$\Rightarrow$ V = 180 Volt

$\therefore \quad C = \frac{Q_1}{V_1} = \frac{360\times10^{-6}}{180} = 2 \times 10^{-6}\mathrm{F} = 2\mu\mathrm{F}$

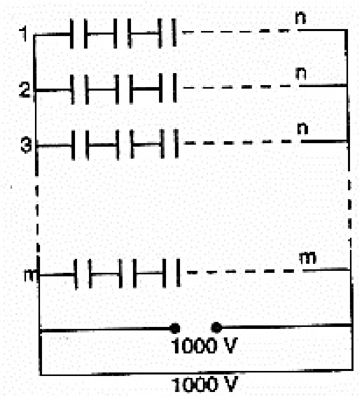
Hence, the applied potential, V = 180 Volt and unknown capacitance of the capacitor is 2μF.

ii. Let Q be the charge stored in the capacitor

Q = CV= $2 \times 10^{-6} \times$ (120+180)

$\Rightarrow$ Q = 6×10^{-4}C

15. Let possible arrangement requires N capacitors of each $1\mu F$ is n capacitors in series and m series arrangement in parallel



Total capacitors $N = m \times n$

As arrangement works on 1000 V.

P.D. across each capacitor in series arrangement is 400 V given

So $\frac{1000}{n} = 400$

n = 2.5

As number of capacitor cannot be in fraction $\therefore$ n = 3 equivalent capacitors in each row of series.

$\frac{1}{C_s} = \left[\frac{1}{n} + \frac{1}{n} + \ldots . n\,lines\right] = \frac{1}{C_s} = m$

$C_s = \frac{1}{n}\mu F$ as the $\frac{1}{n}$ capacitors are in m rows so resultant capacitance of all capacitors equal to $\frac{1}{n} + \frac{1}{n} + \frac{1}{n} \ldots + m$ lines = 2

$\frac{m}{n} = 2 \Rightarrow \frac{m}{3} = 2$

m = 6 rows

n = 6×3 = 18