ELECTRIC POTENTIAL & CAPACITANCE

Class 12 - Physics

Section A

1. Two parallel plate capacitors of capacitances C and 2C are connected in parallel and charged to a potential difference V by a battery. The battery is then disconnected and the space between the plates of capacitor C is completely filled with a material of dielectric constant K = 3. The potential difference across the capacitors now becomes **[1]**

   a) $\frac{3V}{5}$ b) $\frac{2V}{5}$

   c) $\frac{3V}{6}$ d) $\frac{V}{4}$

2. The voltage of clouds is 4×10^6 V with respect to ground. In a lightning strike lasting 0.1 s, a charge of 4 C is delivered to the ground. The power of the lightning strike is: **[1]**

   a) 80 MW b) 160 MW

   c) 20 MW d) 500 MW

[2006]

3. Potential energy of two equal positive charges 1μC each held 1m apart in air is **[1]**

   a) 9×10^{-3} eV b) Zero

   c) 9×10^{-3} J d) 1 J

4. How many 1μF capacitors must be connected in parallel to store a charge of 1C with a potential of 110 V across the capacitors? **[1]**

   a) 990 b) 909

   c) 900 d) 9090

[2011]

5. n identical capacitors joined in parallel are changed to a common potential V. The battery is disconnected. Now, the capacitors are separated and joined in series. For the new combination: **[1]**

   a) energy will remain same, potential difference will become nV

   b) energy and potential difference both will remain unchanged

   c) energy will become n times, potential difference will remain V.

   d) energy and potential both will become n times

6. A conducting sphere of radius R carrying charge Q lies inside an uncharged conducting shell of radius 2R. If they are joined by a metal wire, the amount of heat that will be produced is **[1]**

   a) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{R}$ b) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{2R}$

c) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{4R}$

d) $\frac{2}{4\pi\varepsilon_0} \cdot \frac{Q^2}{3R}$

[2009]

7. An electric charge 10^{-3} μ C is placed at the origin (0, 0) of the (x-y) coordinate system. Two points A and B are situated at $(\sqrt{2}, \sqrt{2})$ and (2, 0) respectively. The potential difference between points A and B will be **[1]**

a) 2 volt

b) 9 volt

c) 4.5 volt

d) zero

8. An electric dipole consisting of charges +q and -q separated by a distance r, is kept symmetrically at the centre of an imaginary sphere of radius R (> r). Another point charge Q is also kept at the centre of the sphere. The net electric flux coming out of the sphere will be **[1]**

a) $\frac{-Q}{\varepsilon_0}$

b) $\frac{-(2q+Q)}{4\pi\varepsilon_0}$

c) $\frac{Q}{\varepsilon_0}$

d) $\frac{2q+Q}{\varepsilon_0}$

[2020]

9. Submarine cables act as **[1]**

a) cylindrical capacitor with inner cylinder earthed

b) parallel plate capacitor

c) cylindrical capacitor with outer cylinder earthed

d) spherical capacitor

10. The effective capacitance of two capacitors of capacitances C_1 and C_2 (with $C_2 > C_1$) connected in parallel is $\frac{25}{6}$ times the effective capacitance when they are connected in series. The ratio $\frac{C_2}{C_1}$ is **[1]**

a) $\frac{4}{3}$

b) $\frac{25}{6}$

c) $\frac{3}{2}$

d) $\frac{5}{3}$

11. No work is done in moving test charge over an equi-potential surface. Why? **[1]**

12. An uncharged insulated conductor A is brought near a charged insulated conductor B. What happens to the charge and potential of B? **[1]**

13. Define dielectric constant in terms of the capacitance of a capacitor. **[1]**

[2006]

14. What are the expressions for energy of a charged capacitor? **[1]**

15. Suppose a charge $+Q_1$ is given to the positive plate and a charge $-Q_2$ to the negative plate of a capacitor. What is the charge on the capacitor? **[1]**

16. During lightning, it is safest to sit inside a car rather than near a tree. Why? **[1]**

17. Why do the equipotential surfaces due to a uniform electric field not intersect each other? **[1]**

[2012]

18. A spherical shell with radius a and charge Q is expanded to radius b. What is the work done by the electrostatic force in this process? **[1]**

19. A small test charge is released at rest at a point in an electrostatic field configuration. Will it travel along the field line passing through that point? **[1]**

20. Guess a possible reason why water has a much greater dielectric constant (= 80) than say, mica (= 6). **[1]**

Section B

21. Match the following: **[2]**

(a) On inserting dielectric between plates of capacitor	(i) energy stored by capacitor increases
(b) On inserting metallic conductor between plates of conductor	(ii) capacitance remains unaffected
(c) Area of plates and distance between plates is doubled	(iii) capacitor gets discharged
(d) Voltage applied to plates of capacitor increases	(iv) capacitance increases

22. Match the following: **[2]**

(a) electric field inside the hollow charged sphere	(i) constant
(b) electric potential inside the hollow charged sphere	(ii) varies inversely to distance
(c) electric field outside the charged sphere	(iii) zero
(d) electric potential outside the charged sphere	(iv) varies inversely to square of distance

23. Match the following: **[2]**

(a) conservative forces	(i) electric field
(b) equipotential surfaces	(ii) energy stored per unit volume
(c) energy density	(iii) work done is zero
(d) negative of potential gradient	(iv) work done depends only upon initial and final positions

24. Match the following: **[2]**

(a) capacitance	(i) N/C
(b) potential	(ii) no unit
(c) dielectric constant	(iii) volt
(d) electric field	(iv) farad

25. Match the following: **[2]**

(a) potential due to point charge	(i) varies inversely to the square of distance
(b) electric field due to point charge	(ii) varies directly with product of charges and inversely to the square of distance
(c) electric potential energy	(iii) potential per unit length
(d) potential gradient	(iv) varies inversely with distance

26. Match the following: **[2]**

(a) farad	(i) joule/coulomb
(b) volt	(ii) electron volt
(c) energy density	(iii) coulomb/volt
(d) electric potential energy	(iv) joule/m^3

27. Match the following: **[2]**

(a) common potential	(i) inversely proportional to distance between plates
(b) energy of capacitor	(ii) potential acquired when two capacitors are connected

(c) capacity of parallel plate capacitor	(iii) capacity increases
(d) capacity of capacitor with dielectric material	(iv) energy stored in capacitor plates

28. Match the following: **[2]**

(a) Capacitance in series combination	(i) total capacitance increases
(b) Capacitance in parallel combination	(ii) electric field decreases
(c) While charging the capacitor	(iii) total capacitance decreases
(d) On inserting dielectric between the plates of capacitor	(iv) capacitance remains unaffected

29. Match the following: **[2]**

(a) potential is same	(i) zero
(b) number of electric field lines crossing the surface	(ii) increases
(c) electric flux due to dipole	(iii) equipotential surface
(d) capacity on inserting dielectric in plates of capacitor	(iv) electric flux

30. Match the following: **[2]**

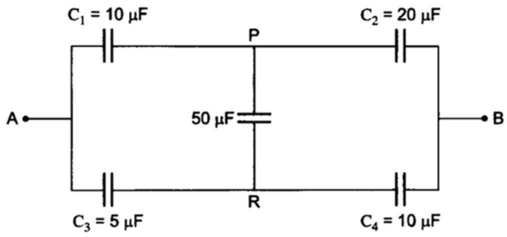
(a) equipotential surface due to point charge	(i) close spherical shells
(b) equipotential surface due to uniform electric field	(ii) spherical surface
(c) equipotential surface due to dipole	(iii) plane surface
(d) equipotential surfaces near the point charges	(iv) oval shape

31. A parallel plate capacitor, of capacitance 20 μF, is connected to a 100 V supply. After some time, the battery is disconnected, and the space, between the plates of the capacitor, is filled with a dielectric of dielectric constant 5. Calculate the energy stored in the capacitor: **[2]**

   i. Before
   ii. After the dielectric has been put in between its plates.

[2016]

32. Describe how can we determine the electric potential at a point from the knowledge of the electric field. **[2]**
33. What is electrostatic potential energy? Where does it reside? **[2]**
34. Calculate the equivalent capacitance between points A and B in the circuit below. If a battery of 10 V is connected across A and B, calculate the charge drawn from the battery by the circuit. **[2]**



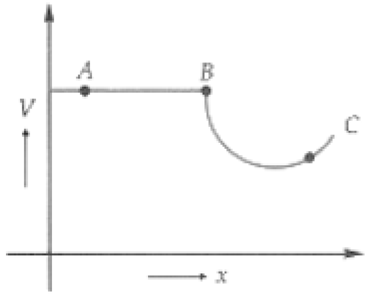
35. n identical capacitors are joined in parallel and the combination is given a potential difference V. If these capacitors be disconnected and joined in series, what potential difference will be obtained across the combination? **[2]**
36. A 3 mm thick mica sheet (of dielectric constant = 6) were inserted between the plates, **[2]**

   i. while the voltage supply remains connected
   ii. after the supply was disconnected.

37. Define the electrical capacitance of a conductor. On what factors does it depend? **[2]**

38. Consider two conducting spheres of radii R_1 and R_2 with $R_1 > R_2$. If the two are at the same potential, the larger sphere has more charge than the smaller sphere. State whether the charge density of the smaller sphere is more or less than that of the largest one. **[2]**

39. The figure shows the variation of electrostatic potential V with distance x for a given charge **[2]**



distribution. From the points marked A, B, and C, identify the point at which the electric field is:

i. zero
ii. maximum

Explain your answer in each case.

40. Connect three capacitors of 3μF, 3μF and 6μF such that their equivalent capacitance is 5μF. **[2]**

Section C

41. A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q. **[3]**

a. A charge q is placed at the centre of the shell, What is the surface charge density on the inner and outer surfaces of the shell?
b. Is the electric field inside a cavity (with no charge) zero even if the shell is not spherical, but has any irregular shape? Explain.

42. **[3]**

a. Determine the electrostatic potential energy of a system consisting of two charges 7 μC and -2 μC (and with no external field) placed at (-9 cm, 0, 0) and (9 cm, 0, 0) respectively.
b. How much work is required to separate the two charges infinitely away from each other?
c. Suppose that the same system of charges is now placed in an external electric field E = A $(\frac{1}{r^2})$; A = 9×10^5 NC^{-1} m^2. What would the electrostatic energy of the configuration be?

43. **[3]**

a. Explain briefly, using a proper diagram, the difference in behaviour of a conductor and a dielectric in the presence of external electric field.
b. Define the term polarization of a dielectric and write the expression for a linear isotropic dielectric in terms of electric field.

[2019]

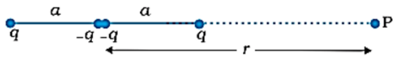
44. Describe schematically the equipotential surfaces corresponding to: **[3]**

a. a constant electric field in the z-direction.
b. a field that uniformly increases in magnitude but remains in a constant (say, z) direction,
c. a single positive charge at the origin
d. a uniform grid consisting of long equally spaced parallel charged wires in a plane.

45. Two charges $5 \times 10^{-8} C$ and $-3 \times 10^{-8} C$ are located 16 cm apart. At what points on the line joining the two charges in the electric potential zero? Take the potential at infinity to be zero. **[3]**

46. The given figure shows a charge array known as an electric quadrupole. For a point on the axis of the **[3]**

quadrupole, obtain the dependence of potential on r for $\frac{r}{a}$ >> 1, and contrast your results with that due to an electric dipole, and an electric monopole (i.e., a single charge).



47. Why does the capacitance of a conductor increase, when an earth connected conductor is brought near it? Briefly explain. **[3]**

48. Obtain an expression for the electric potential at a point due to a group of N point charges. **[3]**

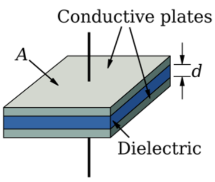
49. **[3]**
   i. Two circular metal plates, each of radius 10 cm, are kept parallel to each other at a distance of 1mm What kind of capacitor do they make? Mention one application of this capacitor.
   ii. If the radius of each of the plates is increased by a factor of $\sqrt{2}$ and their distance of separation decreased to half of its initial value, calculate the ratio of the capacitance in the two cases.
   iii. Suggest anyone possible method by which the capacitance in the second case be increased by n times.

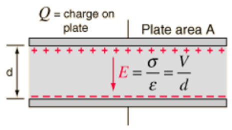
50. A capacitor is charged with a battery and then its plate separation is increased without disconnecting the battery. What will be the change in **[3]**
   a. charge stored in the capacitor?
   b. energy stored in the capacitor?
   c. potential difference across the plates of the capacitor?
   d. electric field between the plates of the capacitor?

Section D

51. **Read the source given below and answer any four out of the following questions:** **[4]**

Capacitance is the ratio of the change in the electric charge of a system to the corresponding change in its electric potential. Capacitors consist of two parallel conductive plates (usually a metal) which are prevented from touching each other (separated) by an insulating material called the “dielectric”. When a voltage is applied to these plates an electrical current flows charging up one plate with a positive charge with respect to the supply voltage and the other plate with an equal and opposite negative charge. The generalized equation for the capacitance of a parallel plate capacitor is given as: $C = k\epsilon_0 \frac{A}{d}$ where ε_0 represents the absolute permittivity of the dielectric material being used, and the charge is given by q = CV





   i. When a conductor is placed in an electric field, the field inside the conductor is:-
      a. positive
      b. negative
      c. constant
      d. zero
   ii. The charge on a capacitor is doubled. Its capacity becomes k times where k:
      a. k = 2
      b. k = 1
      c. k = 0.5
      d. k = 0
   iii. Why does the capacitor block dc signal at a steady-state?

a. Due to the high frequency of dc signal

b. Due to the zero frequency of dc signal

c. The capacitor does not pass any current at a steady-state

d. Due to zero frequency of dc signal

iv. What is the value of capacitance of a capacitor which has a voltage of 4V and has 16C of charge?

a. 2F

b. 4F

c. 6F

d. 8F

v. Capacitor blocks ________ after long time.

a. alternating current

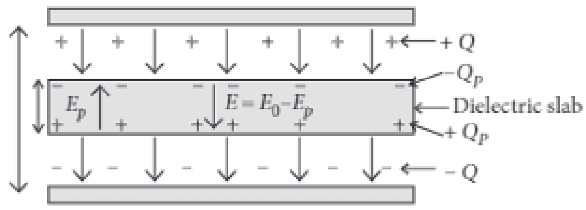
b. direct current

c. both (a) and (b)

d. none of these

52. **Read the source given below and answer any four out of the following questions:** **[4]**

A dielectric slab is a substance which does not allow the flow of charges through it but permits them to exert electrostatic forces on one another. When a dielectric slab is placed between the plates, the field E_0 polarises the dielectric. This induces charge $-Q_p$ on the upper surface and $+Q_p$ on the lower surface of the dielectric. These induced charges set up a field E_p inside the dielectric in the opposite direction of $\vec{E}_0$ as shown.



i. In a parallel plate capacitor, the capacitance increases from 4 μF to 80 μF, on introducing a dielectric medium between the plates. What is the dielectric constant of the medium?

a. 10

b. 20

c. 50

d. 100

ii. A parallel plate capacitor with air between the plates has a capacitance of 8 pF. The separation between the plates is now reduced half and the space between them is filled with a medium of dielectric constant 5. Calculate the value of capacitance of the capacitor in second case.

a. 8 pF

b. 10 pF

c. 80 pF

d. 100 pF

iii. A dielectric introduced between the plates of a parallel plate condenser

a. decreases the electric field between the plates

b. increases the capacity of the condenser

c. increases the charge stored in the condenser

d. increases the capacity of the condenser

iv. A parallel plate capacitor of capacitance 1 pF has separation between the plates is d. When the distance of separation becomes 2d and wax of dielectric constant x is inserted in it the capacitance becomes 2pF. What is the value of x?

a. 2

b. 4

c. 6

d. 8

v. A parallel plate capacitor having area A and separated by distance d is filled by copper plate of thickness b. The new capacity is

a. $\frac{\varepsilon_0 A}{d+\frac{b}{2}}$

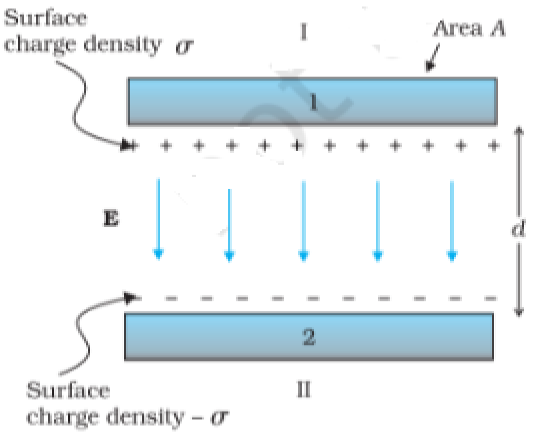
b. $\frac{\varepsilon_0 A}{2d}$

c. $\frac{\varepsilon_0 A}{d-b}$

d. $\frac{2\varepsilon_0 A}{d+\frac{b}{2}}$

53. **Read the source given below and answer any four out of the following questions:** **[4]**

Once the opposite charges have been placed on either side of a parallel-plate capacitor, the charges can be used to do work by allowing them to move towards each other through a circuit. The total energy that can be extracted from a fully charged capacitor is given by the equation: U = $\frac{1}{2}$ CV^2



i. Amount of energy stored in a capacitor of $5\mu F$ when it is charged to a potential difference of 250 V:

a. 0.156 joule

b. 1 joule

c. 0.25 joule

d. 0.125 joule

ii. A condenser is charged to double its initial potential. The energy stored becomes x times, where x is

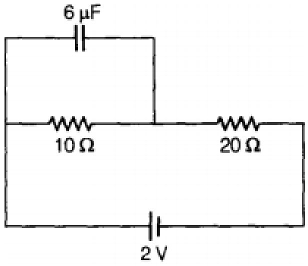
a. 2

b. 4

c. 1

d. 0.5

iii. Find the charge on the capacitor as shown in the circuit.



a. $3\mu C$

b. $6\mu C$

c. $8\mu C$

d. $4\mu C$

iv. The capacitance is a circuit component that opposes the change in the circuit _____ .

a. Current

b. Voltage

c. Impedance

d. None of these

v. In a region of constant potential:

a. the electric field is uniform

b. the electric field is zero

c. there can be no charge inside the region

d. both b and c

54. **Read the source given below and answer any four out of the following questions:** **[4]**

This energy possessed by a system of charges by virtue of their positions. When two like charges lie infinite distance apart, their potential energy is zero because no work has to be done in moving one charge at infinite distance from the other.

In carrying a charge q from point A to point B, work done W = q(V_A - V_B). This work may appear as change in KE/PE of the charge. The potential energy of two charges q_1 and q_2 at a distance r in air is $\frac{q_1 q_2}{4\pi\varepsilon_0 r}$. It is measured in joule. It may be positive, negative or zero depending on the signs of q_1 and q_2.

i. Calculate work done in separating two electrons form a distance of 1 m to 2 m in air, where e is electric charge and k is electrostatic force constant.

a. ke^2

b. $\frac{e^2}{2}$

c. $\frac{-ke^2}{2}$

d. zero

ii. Four equal charges q each are placed at four corners of a square of side a each. Work done in carrying a charge -q from its centre to infinity is

i. zero

ii. $\frac{\sqrt{2}q^2}{\pi\varepsilon_0 a}$

iii. $\frac{\sqrt{2}q}{\pi\varepsilon_0 a}$

iv. $\frac{q^2}{\pi\varepsilon_0 a}$

iii. Two points A and B are located in diametrically opposite directions of a point charge of +2 μ C at distances 2 m and 1 m respectively from it. The potential difference between A and B is

a. 3×10^3 V

b. 6×10^4 V

c. -9×10^3 V

d. -3×10^3 V

iv. Two-point charges A = +3 nC and B = +1 nC are placed 5 cm apart in air. The work done to move charge B towards A by 1 cm is

a. 2.0×10^{-7} J

b. 1.35×10^{-7} J

c. 2.7×10^{-7} J

d. 12.1×10^{-7} J

v. A charge Q is placed at the origin. The electric potential due to this charge at a given point in space is V. The work done by an external force in bringing another charge q from infinity up to the point is

a. $\frac{V}{q}$

b. Vq

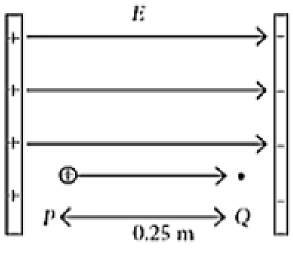
c. V + q

d. V

55. **Read the source given below and answer any four out of the following questions:** **[4]**

Potential difference (ΔV) between two points A and B separated by a distance x, in a uniform electric field E is given by $\Delta V = -Ex$, where x is measured parallel to the field lines. If a charge q_0 moves from P to Q, the change in potential energy (ΔU) is given as $\Delta U = q_0 \Delta V$. A proton is released from rest in uniform electric field of magnitude 4.0×10^8 Vm^{-1} directed along the positive X-axis. The proton undergoes a displacement of 0.25 m in the direction of E.

Mass of a proton = 1.66×10^{-27} kg and charge of proton = 1.6×10^{-19} C



i. The change in electric potential of the proton between the points A and B is

a. -1×10^8 V

b. 1×10^8 V

c. 6.4×10^{-19} V

d. -6.4×10^{-19} V

ii. The change in electric potential energy of the proton for displacement from A to B is

a. 1.6×10^{11} J

b. 0.5×10^{23} J

c. -1.6 $\times$ 10^{-11} J

d. 3.2 $\times$ 10^{22} J

iii. The mutual electrostatic potential energy between two protons which are at a distance of 9 $\times$ 10^{-15} m, in $_{92}U^{235}$ nucleus is

a. 1.56 $\times$ 10^{-14} J

b. 5.5 $\times$ 10^{-14} J

c. 2.56 $\times$ 10^{-14} J

d. 4.56 $\times$ 10^{-14} J

iv. If a system consists of two charges 4 mC and -3 mC with no external field placed at (-5 cm, 0,0) and (5 cm, 0,0) respectively. The amount of work required to separate the two charges infinitely away from each other is

a. -1.1 J

b. 2 J

c. 2.5 J

d. 3 J

v. As the proton moves from P to Q, then

a. the potential energy of proton decreases

b. the potential energy of proton increases

c. the proton loses kinetic energy

d. total energy of the proton increases.

Section E

56. i. Obtain the expression for the capacitance of a parallel plate capacitor with a dielectric medium between its plates. **[5]**

ii. A charge of 6 μC is given to a hollow metallic sphere of radius 0.2 m. Find the potential at (i) the surface and (ii) the centre of the sphere.

[2024]

57. A parallel plate capacitor is charged to a potential difference V by a DC source. The capacitor is then disconnected from the source. If the distance between the plates is doubled, state with reason, how the following will change - **[5]**

i. Electric field between the plates?

ii. Capacitance?

iii. Energy stored in the capacitor?

[2016, 2011, 2010]

58. Briefly explain the principle of a capacitor. Derive an expression for the capacitance of a parallel plate capacitor, whose plates are separated by a dielectric medium. **[5]**

59. Show that the potential energy of a dipole making angle θ with the direction of the field is given by $U(\theta) = -\vec{P} \cdot \vec{E}$. Hence find out the amount of work done in rotating it from the position of unstable equilibrium to the stable equilibrium. **[5]**

60. Define the terms (i) capacitance of a capacitor (ii) dielectric strength of a dielectric. When a dielectric is inserted between the plates of a charged parallel plate capacitor, fully occupying the intervening region, how does the **[5]**

polarization of the dielectric medium affect the net electric field? For linear dielectrics, show that the introduction of a dielectric increases its capacitance by a factor κ, characteristic of the dielectric.

[2008]