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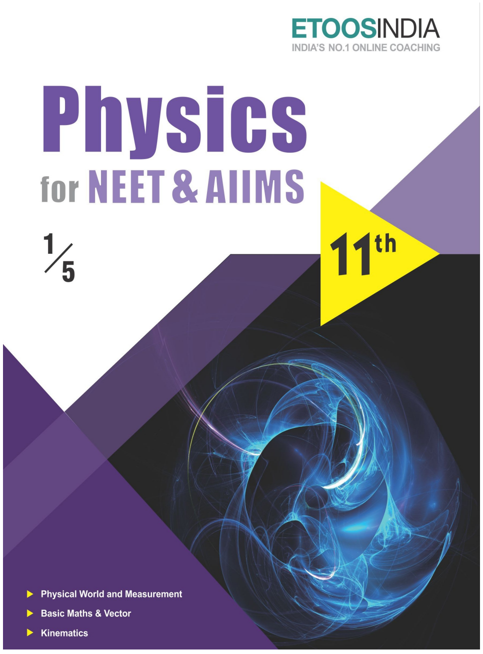
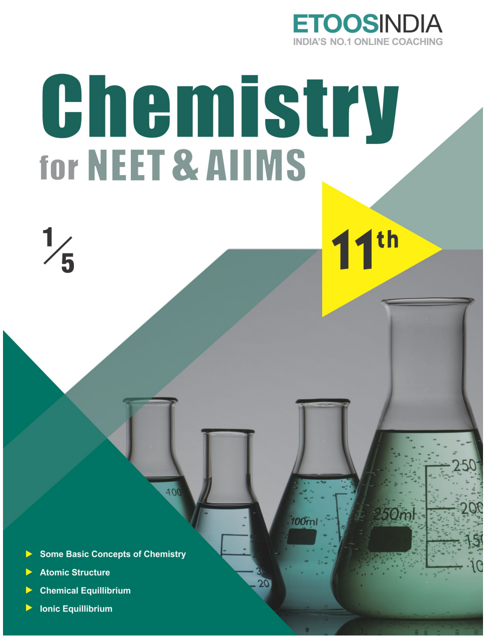
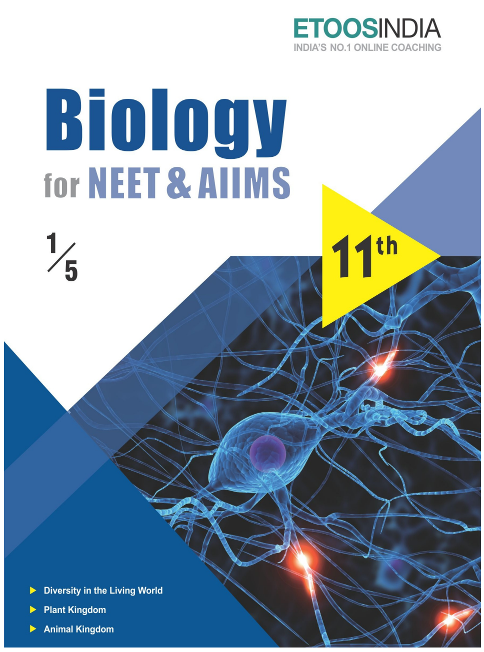
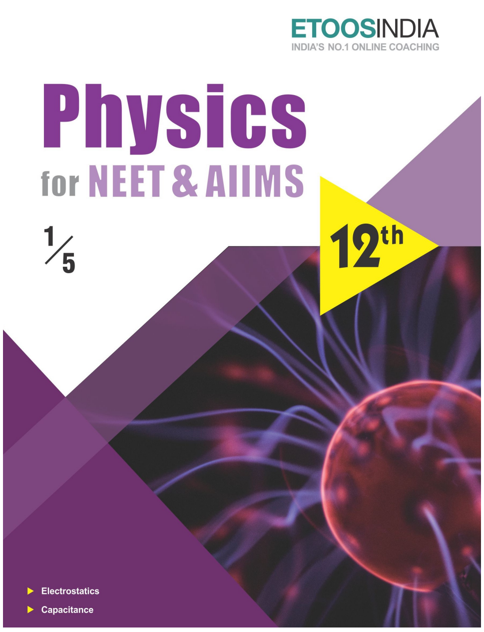
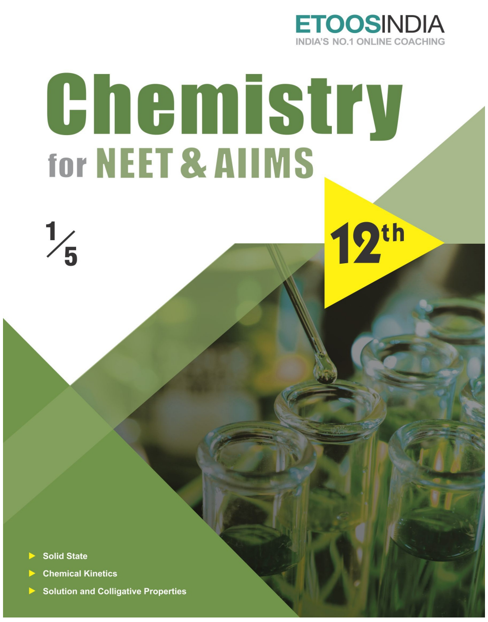
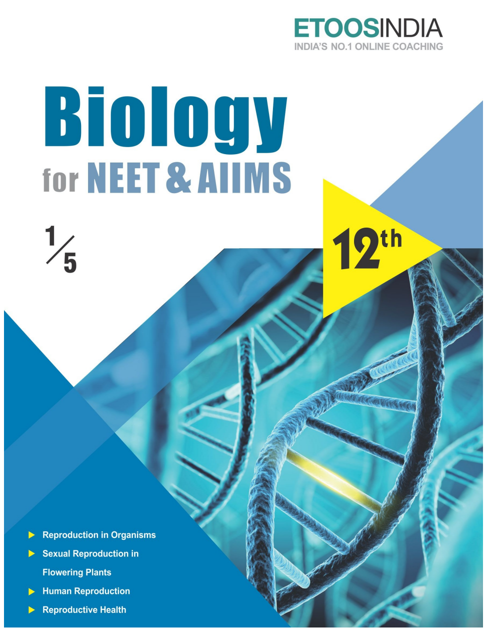












ETOOS Comprehensive Study Material For NEET & AIIMS

CHAPTER 02

CAPACITANCE

A natural law regulates the advance of science. Where only observation can be made, the growth of knowledge creeps; where laboratory experiments can be carried on, knowledge leaps forward.

"MICHAEL FARADAY"

INTRODUCTION

Capacitor is an arrangement of two conductors generally carrying charges of equal magnitudes and opposite sign and separated by an insulating medium. A capacitor is a device which stores electric charge. Capacitors vary in shape and size, but the basic configuration is two conductors carrying equal but opposite chagres (Figure). Capacitors have many important applications in electronics. Some examples include storing electric potential energy, delaying voltage changes when coupled with resistors, filtering out unwanted frequency signals, forming resonant circuits and making frequency- dependent and independent voltage divides when combined with resistors, Some of these applications will be discussed in latter chapters.

When charges are pulled apart, energy is associated with the pulling apart of charges, just like energy is involved in stretching a spring. Thus, some energy is stored in capacitors.

In the uncharged staste, the charge on eitherone of the conductors in the capacitor is zero. During the charging process, a charge Q is moved from one conductor to the other one, giving one conductor a charge +Q, and the other one a charge – Q. A potential difference ΔV is created, with the positively charged conductor at a higher potential than the negatively charged conductor. Note that whether charged or uncharged, the net charge on the capacitor as a whole is zero.

(ii) The total charge Q is shared by each capacitor in the direct ratio of the capacitances. $Q = Q_1 + Q_2 + Q_3$

If C_P is the net capacitance for the parallel combination of capacitors :

$$C_PV = C_1V + C_2V + C_3V \Rightarrow C_P = C_1 + C_2 + C_3$$

ETOOS KEY POINTS

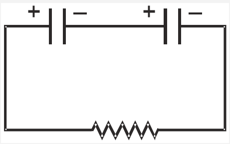
(i) For a given voltage to store maximum energy capacitors should be connected in parallel.

(ii) If N identical capacitors each having breakdown voltage V are joined in

(a) series then the break down voltage of the combination is equal to NV

(b) parallel then the breakdown voltage of the combination is equal to V.

(iii) Two capacitors are connected in series with a battery. Now battery is removed and loose wires connected together then final charge on each capacitor is zero.



(iv) If N identical capacitors are connected then $C_{series} = \frac{C}{N}$, $C_{parallel} = NC$

(v) In DC capacitor's offers infinite resistance in steady state, so there will be no current flows through capacitor branch.

Ex. Capacitor C, 2C, 4C, ... ∞ are connected in parallel, then what will be their effective capacitance ?

Sol. Let the resultant capacitance be $C_{resultant} = C + 2C + 4C + ...\infty = C[1 + 2 + 4 + ...\infty] = C \times \infty = \infty$

Ex. An infinite number of capacitors of capacitance C, 4C, 16C ... ∞ are connected in series then what will be their resultant capacitance ?

Sol. Let the equivalent capacitance of the combination = C_{eq}

$$\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{4C} + \frac{1}{16C} + ...\infty = \left[1 + \frac{1}{4} + \frac{1}{16} + ...\infty\right]\frac{1}{C}$$ (this is G. P.series)

$$\Rightarrow S_\infty = \frac{a}{1-r}$$ first term a = 1, common ratio $r = \frac{1}{4} \Rightarrow \frac{1}{C_{eq}} = \frac{1}{1-\frac{1}{4}} \times \frac{1}{C} \Rightarrow C_{eq} = \frac{3}{4}C$

Effect of Dielectric

(i) The insulators in which microscopic local displacement of charges takes place in presence of electric field are known as **dielectrics**.

(ii) Dielectrics are non conductors upto certain value of field depending on its nature. If the field exceeds this limiting value called **dielectric strength** they lose their insulating property and begin to conduct.

(iii) **Dielectric strength** is defined as the maximum value of electric field that a dielectric can tolerate without breakdown. Unit is volt/metre. Dimensions $M^1L^1T^{-3}A^{-1}$

Polar Dielectrics

(i) In absence of external field the centres of positive and negative charge do not coincide-due to asymmetric shape of molecules.

(ii) Each molecule has permanent dipole moment.

(iii) The dipole are randomly oriented so average dipole moment per unit volume of polar dielectric in absence of external field is nearly zero.

Etoos Tips & Formulas

1. CAPACITOR & CAPACITANCE

A capacitor consist of two conductors carrying charges of equal magnitude and opposite sign. The capacitance C of any capacitor is the ratio of the charge Q on either conductor to the potential difference V between them $C = \frac{Q}{V}$ The capacitance depends only on the geometry of the conductors and not on an external source of charge or potential difference.

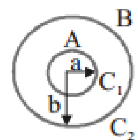
2. Capacitance of an Isolated Spherical Conductor

$C = 4\pi \in_0 \in_r R$ in a medium $C = 4\pi \in_0 R$ in air

This sphere is at infinite distance from all the conductors.

3. Spherical Capacitor :

It consists of two concentric spherical shells. Here capacitance on region between the two shells is C_1 and that outside the shell is C_2. We have



$$C_1 = \frac{4\pi \in_0 ab}{b-a} \text{ and } C_2 = 4\pi \in_0 b$$

4. Parallel Plate Capacitor :

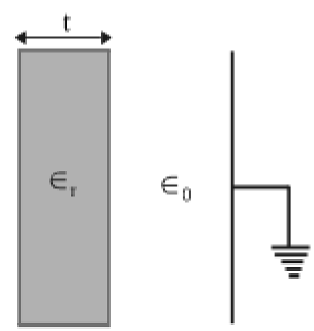
(a) **Uniform Di-Electric Medium :** If two parallel plates each of area A & separated by a distance d are charged with equal & opposite charge Q, then the system is called a parallel plate capacitor & capacitance is given by,

$$C = \frac{4\pi \in_0 \in_r A}{d} \text{ in a medium ; } C = \frac{\in_0 A}{d} \text{ with air as medium}$$

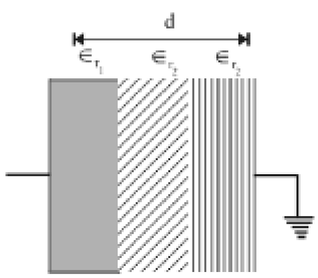
This result is only valid when the electric field between plates of capacitor is constant.

(b) **Medium Partly Air :** $C = \dfrac{\in_0 A}{d - \left(t - \dfrac{t}{\in_r}\right)}$

When a di-electric slab of thickness t & relative permittivity $\in_r$ is introduced between the plates of an air capacitor, then the distance between the plates is effectively reduced by $\left(t - \frac{t}{\in_r}\right)$ irrespective of the position of the di-electric slab.



(c) **Composite Medium :**



$$C = \frac{\in_0 A}{\frac{t_1}{\in_{r_1}} + \frac{t_2}{\in_{r_2}} + \frac{t_3}{\in_{r_3}}}$$

SOLVED EXAMPLE

Ex. 1 Seven capacitors, each of capacitance 2μF are to be connected to obtain a capacitance of 10/11 μF. Which of the following combinations is possible ?

(A) 5 in parallel 2 in series

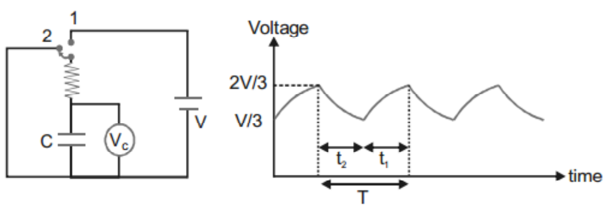
(B) 4 in parallel 3 in series

(C) 3 in parallel 4 in series

(D) 2 in parallel 5 in series

Sol. 5(2μF) in series with $\left(\frac{2\mu F}{2}\right)$, 10μF in series with 1μF, $C_{eq} = \frac{10 \times 1}{10+1} = \frac{10}{11}\mu F$

Ex. 2 The switch in circuit shifts from 1 to 2 when $V_C > 2V/3$ and goes back to 1 from 2 when $V_C < V/3$. The voltmeter reads voltage as plotted. What is the period T of the wave form in terms of R and C?



Sol. During time 't_2' capacitor is discharging with the help of resistor 'R' $\therefore\ q = q_0 e^{-t/RC}$

$V = V_0\ e^{-t/RC}$ [∵Q=CV]

As $V_0 = \frac{2V}{3}$; $V = \frac{V}{3}$; $t_2 = RC\ \ell n2$

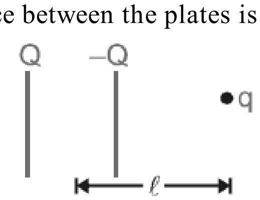
During time 't_1' capacitor is charging with the help of battery.

$\therefore\ q = q_0\ (1-e^{-t/RC})$ or $V = V_0\ (1-e^{-t/RC})$

as $V_0 = \frac{2V}{3}$; $V = \frac{V}{3}$; $t_1 = RC\ \ell n2$

$T = t_1 + t_2 = 2RC\ \ell n2$

Ex. 3 The plates of very small size of a parallel plate capacitor are charged as shown .The force on the charged particle of charge 'q' at a distance 'ℓ' from the capacitor is : (Assume that the distance between the plates is $d << \ell$)



(A) Zero

(B) $\frac{Qqd}{2\pi \epsilon_0 \ell^3}$

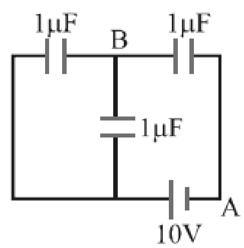
(C) $\frac{Qqd}{\pi \epsilon_0 \ell^3}$

(D) $\frac{Qqd}{4\pi \epsilon_0 \ell^3}$

Sol. Assume capacitor as dipole and use $F = qE$,

$E = \frac{2kp}{r^3}$, $p = Qd$

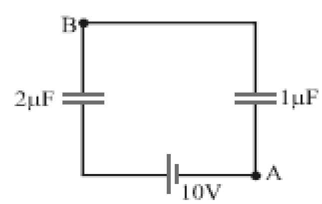
Ex. 4 In the circuit shown, if potential of A is 10V, then potential of B is -



Sol. Given circuit can be reduced as

Charge on capacitors $= \left(\frac{2}{3}\right)(10)\mu C$

Now $V_B - V_A = \left(\frac{20}{3}\right)(1) = \frac{20}{3}$



$\Rightarrow\ V_B = V_A + \frac{20}{3} = 10 + \frac{20}{3} = \frac{50}{3} V$

Ex. 5 A, B and C are three large, parallel conducting plates, placed horizontally. A and C are rigidly fixed and earthed. B is given some charge. Under electrostatic and gravitational forces, B may be –

Exercise # 1

SINGLE OBJECTIVE | NEET LEVEL

1. The capacity of a parallel plate condenser is $5\,\mu F$. When a glass plate is placed between the plates of the conductor, its potential becomes $1/8th$ of the original value. The value of dielectric constant will be

(A) 1.6 (B) 5
(C) 8 (D) 40

2. A capacitor is charged by using a battery which is then disconnected. A dielectric slab is then slipped between the plates, which results in

(A) Reduction of charge on the plates and increase of potential difference across the plates
(B) Increase in the potential difference across the plate, reduction in stored energy, but no change in the charge on the plates
(C) Decrease in the potential difference across the plates, reduction in the stored energy, but no change in the charge on the plates
(D) None of the above

3. The energy of a charged capacitor is given by the expression (q = charge on the conductor and C = its capacity)

(A) $\frac{q^2}{2C}$ (B) $\frac{q^2}{C}$
(C) $2qC$ (D) $\frac{q}{2C^2}$

4. The capacity of a condenser is 4×10^{-6} *farad* and its potential is 100 *volts*. The energy released on discharging it fully will be

(A) 0.02 *Joule* (B) 0.04 *Joule*
(C) 0.025 *Joule* (D) 0.05 *Joule*

5. The insulated spheres of radii R_1 and R_2 having charges Q_1 and Q_2 respectively are connected to each other. There is

(A) No change in the energy of the system
(B) An increase in the energy of the system
(C) Always a decrease in the energy of the system
(D) A decrease in the energy of the system unless $Q_1R_2 = Q_2R_1$

6. Which one statement is correct? A parallel plate air condenser is connected with a battery. Its charge, potential, electric field and energy are Q_o, V_o, E_o and U_o respectively. In order to fill the complete space between the plates a dielectric slab is inserted, the battery is still connected. Now the corresponding values Q, V, E and U are in relation with the initially stated as

(A) $Q > Q_o$ (B) $V > V_o$
(C) $E > E_o$ (D) $U > U_o$

7. In a charged capacitor, the energy resides

(A) The positive charges
(B) Both the positive and negative charges
(C) The field between the plates
(D) Around the edge of the capacitor plates

8. The energy stored in a condenser of capacity C which has been raised to a potential V is given by

(A) $\frac{1}{2}CV$ (B) $\frac{1}{2}CV^2$
(C) CV (D) $\frac{1}{2VC}$

9. If two conducting spheres are separately charged and then brought in contact

(A) The total energy of the two spheres is conserved
(B) The total charge on the two spheres is conserved
(C) Both the total energy and charge are conserved
(D) The final potential is always the mean of the original potentials of the two spheres

10. Two insulated charged spheres of radii $20\ cm$ and $25\ cm$ respectively and having an equal charge Q are connected by a copper wire, then they are separated

(A) Both the spheres will have the same charge Q
(B) Charge on the 20 cm sphere will be greater than that on the 25 cm sphere
(C) Charge on the 25 cm sphere will be greater than that on the 20 cm sphere
(D) Charge on each of the sphere will be 2Q

Exercise # 2 SINGLE OBJECTIVE AIIMS LEVEL

1. 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 connected to another battery and is charged to potential difference 2V. The charging batteries are now 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) Zero (B) $\frac{25CV^2}{6}$

(C) $\frac{3CV^2}{2}$ (D) $\frac{9CV^2}{2}$

2. A 40 μF capacitor in a defibrillator is charged to 3000 V. The energy stored in the capacitor is sent through the patient during a pulse of duration 2 ms. The power delivered to the patient is :–

(A) 45 kW (B) 90 kW

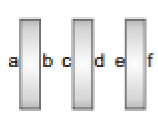
(C) 180 kW (D) 360 kW

3. An automobile spring extends 0.2 m for 5000 N load. The ratio of potential energy stored in this spring when it has been compressed by 0.2 m to the potential energy stored in a 10 μF capacitor at a potential difference of 10000 V will be :–

(A) 1/4 (B) 1

(C) 1/2 (D) 2

4. Three parallel metallic plates, each of area A are kept as shown in the figure and charges Q_1, Q_2 and Q_3 are given to them. Edge effects are negligible. Calculate the charges on the two outermost surfaces 'a' and 'f'.



(A) $\frac{Q_1+Q_2+Q_3}{2}$

(B) $\frac{Q_1+Q_2+Q_3}{3}$

(C) $\frac{Q_1-Q_2+Q_3}{3}$

(D) $\frac{Q_1-Q_2+Q_3}{2}$

5. The distance between plates of a parallel plate capacitor is 'd'. Another thick metal plate of thickness d/2 and area same as that of plates is so placed between the plates, that it does not touch the plates. The capacity of the resultant capacitor :–

(A) remain same (B) becomes double

(C) becomes half (D) becomes one fourth

6. Two conducting spheres of radii R_1 and R_2 are charged with charges Q_1 and Q_2 respectively. On bringing them in contact there is :–

(A) no change in the energy of the system

(B) an increase in the energy of the system if $Q_1R_2 \neq Q_2R_1$

(C) always a decrease in energy of the system

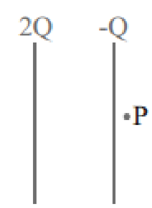
(D) a decrease in energy of the system if $Q_1R_2 \neq Q_2R_1$

7. A capacitor of value 4 μF charged at 50V is connected with another capacitor of value 2μF charged at 100V, in such a way that plates of similar charges are connected together. Before joining and after joining the total energy in multiples 10–2 J will be :–

(A) 1.5 and 1.33 (B) 1.33 and 1.5

(C) 3.0 and 2.67 (D) 2.67 and 3.0

8. In the figure shown the plates of a parallel plate capacitor have unequal charges. Its capacitance is 'C'. P is a point outside the capacitor and close to the plate of charge–Q. The distance between the plates is 'd' then which statement is wrong



(A) A point charge at point 'P' will experience electric force due to capacitor

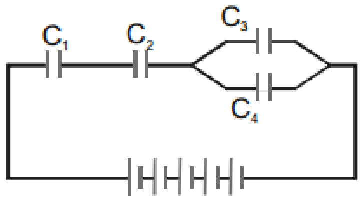
(B) The potential difference between the plates will be $\frac{3Q}{2C}$

(C) The energy stored in the electric field in the region between the plates is $\frac{9Q^2}{8C}$

(D) The force on one plate due to the other plate is $\frac{Q^2}{2\pi \epsilon_0 d^2}$

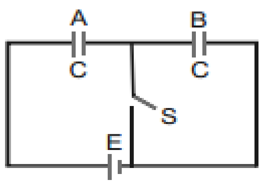
Exercise # 3 | PART - 1 | MATRIX MATCH COLUMN

1. In the circuit shown in figure. $C_1=C$, $C_2=2C$, $C_3=3C$, $C_4=4C$.



	Column I		Column II
(A)	Maximum potential difference	(P)	across C_1
(B)	Minimum potential difference	(Q)	across C_2
(C)	Maximum potential energy	(R)	across C_3
(D)	Minimum potential energy	(S)	across C_4

2. Consider the situation shown. The switch S is open for a long time and then closed. Then :



	Column–I		Column–II
(A)	Charge flown through battery when S is closed	(P)	$\frac{CE^2}{2}$
(B)	Work done by battery	(Q)	$\frac{CE}{2}$
(C)	Charge on capacitor A when switch S is closed	(R)	$\frac{CE^2}{4}$
(D)	Heat developed in the system	(S)	CE

Exercise # 4 PART - 1 PREVIOUS YEAR (NEET/AIPMT)

1. A capacitor is charged by connecting a battery across its plates. It stores energy U. Now the battery is disconnected and another identical capacitor is connected across it, then the energy stored by both capacitors of the system will be [CBSE AIPMT 2000]

(A) U (B) $\frac{U}{2}$

(C) 2U (D) $\frac{3}{2}U$

2. In a parallel plate capacitor, the distance between the plates is d and potential difference across plates us V. Energy stored per unit volume between the plates of capacitor is [CBSE AIPMT 2001]

(A) $\frac{Q^2}{2V^2}$ (B) $\frac{1}{2}\frac{\varepsilon_0 V^2}{d^2}$

(C) $\frac{1}{2}\frac{V^2}{\varepsilon_0 d^2}$ (D) $\frac{1}{2}\varepsilon_0\frac{V^2}{d}$

3. Some charge is being given to a conductor, then its potential is [CBSE AIPMT 2002]

(A) Maximum at surface
(B) Maximum at centre
(C) Same throughout the conductor
(D) Maximum somewhere between surface and centre

4. A capacitor of capacity C_1 is charged upto potential V volt and then connected in parallel to an uncharged capacitor of capacity C_2. The final potential difference across each capacitor will be [CBSE AIPMT 2002]

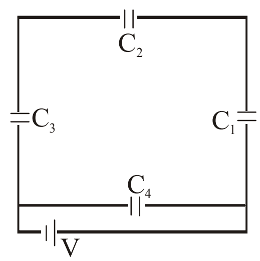
(A) $\frac{C_2 V}{C_1 + C_2}$ (B) $\frac{C_1 V}{C_1 + C_2}$

(C) $\left(1+\frac{C_2}{C_1}\right)V$ (D) $\left(1-\frac{C_2}{C_1}\right)V$

5. Three capacitors each of capacity 4 μE are to be connected in such a way that the effective capacitance is 6μF. This can be done by [CBSE AIPMT 2004]

(A) Connecting two in series and one in parallel
(B) Connecting two in parallel and one in series
(C) Connecting all of them in series
(D) Connecting all of them in parallel

6. A network of four capacitors of capacity equal to $C_1 = C$, $C_2 = 2C$, $C_3 = 3C$ and $C_4 = 4C$ are connected to a battery as shown in the figure. The ratio of the charges on C_2 and C_4 is [CBSE AIPMT 2005]



(A) $\frac{22}{3}$ (B) $\frac{3}{22}$

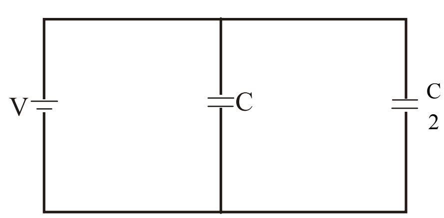
(C) $\frac{7}{4}$ (D) $\frac{4}{7}$

7. A parallel plate air capacitor is charged to a potential difference of V volts. After disconnecting the charging battery the distance between the plates of the capacitor is increased using an insulating handle. As a result the potential difference between the plates [CBSE AIPMT 2006]

(A) Decreases (B) Does not change

(C) Becomes zero (D) Increases

8. Two condensers, one of capacity C and the other of capacity $\frac{C}{2}$, are connected to a V volt battery, as shown. [CBSE AIPMT 2007]



The work done in charging fully both the condensers is

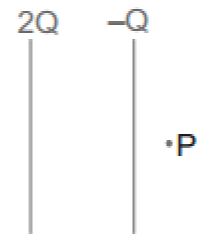
(A) $2CV^2$ (B) $\frac{1}{4}CV^2$

(C) $\frac{3}{4}CV^2$ (D) $\frac{1}{2}CV^2$

MOCK TEST

STRAIGHT OBJECTIVE TYPE

1. In the figure shown the plates of a parallel plate capacitor have unequal charges. Its capacitance is 'C'. P is a point outside the capacitor and close to the plate of charge –Q. The distance between the plates is 'd', select incorrect alternative :



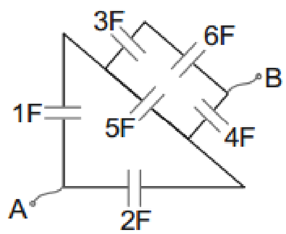
(A) A point charge at point 'P' will experience electric force due to capacitor

(B) The potential difference between the plates will be $\frac{3Q}{2C}$

(C) The energy stored in the electric field in the region between the plates is $\frac{9Q^2}{8C}$

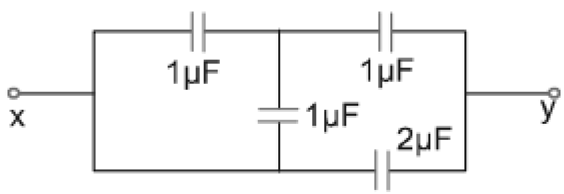
(D) The force on one plate due to the other plate is $\frac{Q^2}{2\pi \epsilon_0 d^2}$

2. In the figure shown the equivalent capacitance between 'A' and 'B' is :



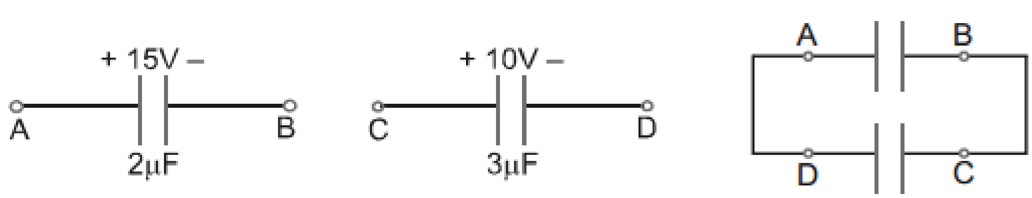
(A) 3.75 F (B) 2 F (C) 21 F (D) 16 F

3. The equivalent capacitance between x & y is:



(A) $\frac{5}{6}$ μF (B) $\frac{7}{6}$ μF (C) $\frac{8}{3}$ μF (D) 1 μF

4. In the figure initial status of capacitance and their connection is shown. Which of the following is incorrect about this circuit :



(A) Final charge on each capacitor will be zero

(B) Final total electrical energy of the capacitors will be zero

11th Class Modules Chapter Details

Physics
5
Modules

Chemistry
5
Modules

Mathematics
5
Modules

PHYSICS

Module-1

1. Physical World & Measurements
2. Basic Maths & Vector
3. Kinematics

Module-2

1. Law of Motion & Friction
2. Work, Energy & Power

Module-3

1. Motion of system of particles & Rigid Body
2. Gravitation

Module-4

1. Mechanical Properties of Matter
2. Thermal Properties of Matter

Module-5

1. Oscillations
2. Waves

CHEMISTRY

Module-1(PC)

1. Some Basic Conceps of Chemistry
2. Atomic Structure
3. Chemical Equilibrium
4. Ionic Equilibrium

Module-2(PC)

1. Thermodynamics & Thermochemistry
2. Redox Reaction
3. States Of Matter (Gaseous & Liquid)

Module-3(IC)

1. Periodic Table
2. Chemical Bonding
3. Hydrogen & Its Compounds
4. S-Block

Module-4(OC)

1. Nomenclature of Organic Compounds
2. Isomerism
3. General Organic Chemistry

Module-5(OC)

1. Reaction Mechanism
2. Hydrocarbon
3. Aromatic Hydrocarbon
4. Environmental Chemistry & Analysis Of Organic Compounds

BIOLOGY

Module-1

1. Diversity in the Living World
2. Plant Kingdom
3. Animal Kingdom

Module-2

1. Morphology in Flowering Plants
2. Anatomy of Flowering Plants
3. Structural Organization in Animals

Module-3

1. Cell: The Unit of Life
2. Biomolecules
3. Cell Cycle & Cell Division
4. Transport in Plants
5. Mineral Nutrition

Module-4

1. Photosynthesis in Higher Plants
2. Respiration in Plants
3. Plant Growth and Development
4. Digestion & Absorption
5. Breathing & Exchange of Gases

Module-5

1. Body Fluids & Its Circulation
2. Excretory Products & Their Elimination
3. Locomotion & Its Movement
4. Neural Control & Coordination
5. Chemical Coordination and Integration

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12th Class Modules Chapter Details

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Modules

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Modules

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5
Modules

PHYSICS

Module-1
1. Electrostatics
2. Capacitance

Module-2
1. Current Electricity
2. Magnetic Effect of Current and Magnetism

Module-3
1. Electromagnetic Induction
2. Alternating Current

Module-4
1. Geometrical Optics
2. Wave Optics

Module-5
1. Modern Physics
2. Nuclear Physics
3. Solids & Semiconductor Devices
4. Electromagnetic Waves

CHEMISTRY

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1. Solid State
2. Chemical Kinetics
3. Solutions and Colligative Properties

Module-2(PC)
1. Electrochemistry
2. Surface Chemistry

Module-3(IC)
1. P-Block Elements
2. Transition Elements (d & f block)
3. Co-ordination Compound
4. Metallurgy

Module-4(OC)
1. HaloAlkanes & HaloArenes
2. Alcohol, Phenol & Ether
3. Aldehyde, Ketone & Carboxylic Acid

Module-5(OC)
1. Nitrogen & Its Derivatives
2. Biomolecules & Polymers
3. Chemistry in Everyday Life

BIOLOGY

Module-1
1. Reproduction in Organisms
2. Sexual Reproduction in Flowering Plants
3. Human Reproduction
4. Reproductive Health

Module-2
1. Principles of Inheritance and Variation
2. Molecular Basis of Inheritance
3. Evolution

Module-3
1. Human Health and Disease
2. Strategies for Enhancement in Food Production
3. Microbes in Human Welfare

Module-4
1. Biotechnology: Principles and Processes
2. Biotechnology and Its Applications
3. Organisms and Populations

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2. Biodiversity and Conservation
3. Environmental Issues

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