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CBSE

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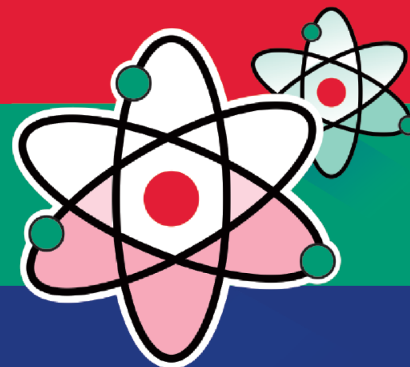

Physics

Class 12 *(Term I)*

- Multiple Choice Questions
- Assertion-Reasoning MCQs
- Case Based MCQs

3 Practice Papers
On Latest Term I Syllabus

Including Chapterwise
Quick Revision Notes

As per CBSE Circular Acad - 51/2021, 05 July 2021 & Acad - 53/2021, 22 July 2021...

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Physics

Class 12 *(Term I)*

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ARIHANT PRAKASHAN (School Division Series)

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Contents

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Syllabus (Rationalised)

(Term I)

Time: 90 Minutes | Max Marks: 35

Units		No. of Periods	Marks
Unit I	**Electrostatics**	23	17
	Chapter–1: Electric Charges and Fields		
	Chapter–2: Electrostatic Potential and Capacitance		
Unit II	**Current Electricity**	15	
	Chapter–3: Current Electricity		
Unit III	**Magnetic Effects of Current and Magnetism**	16	18
	Chapter–4: Moving Charges and Magnetism		
	Chapter–5: Magnetism and Matter		
Unit IV	**Electromagnetic Induction and Alternating Currents**	19	
	Chapter–6: Electromagnetic Induction		
	Chapter 7: Alternating Currents		
	Total	**73**	**35**

UNIT-I Electrostatics *23 Periods*

Chapter-1 Electric Charges and Fields

Electric Charges; Conservation of charge, Coulomb's law-force between two-point charges, forces between multiple charges; superposition principle and continuous charge distribution. Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field. Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet

Chapter-2 Electrostatic Potential and Capacitance

Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two-point charges and of electric dipole in an electrostatic field. Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarisation, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor.

UNIT-II Current Electricity *15 Periods*

Chapter-3 Current Electricity

Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current; Ohm's law, electrical resistance, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity; temperature dependence of resistance. Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's laws and simple applications, Wheatstone bridge, metre bridge **(qualitative ideas only).** Potentiometer - principle and its applications to measure potential difference and for comparing EMF of two cells; measurement of internal resistance of a cell **(qualitative ideas only)**.

UNIT-III Magnetic Effects of Current and Magnetism *16 Periods*

Chapter-4 Moving Charges and Magnetism

Concept of magnetic field, Oersted's experiment. Biot - Savart law and its application to current carrying circular loop. Ampere's law and its applications to infinitely long straight wire. Straight and toroidal solenoids (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields. Force on a current-carrying conductor in a uniform magnetic field, force between two parallel current-carrying conductors-definition of ampere, torque experienced by a current loop in uniform magnetic field; moving coil galvanometer-its current sensitivity and conversion to ammeter and voltmeter.

Chapter-5 Magnetism and Matter

Current loop as a magnetic dipole and its magnetic dipole moment, magnetic dipole moment of a revolving electron, bar magnet as an equivalent solenoid, magnetic field lines; earth's magnetic field and magnetic elements.

UNIT-IV Electromagnetic Induction and Alternating Currents *19 Periods*

Chapter-6 Electromagnetic Induction

Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Eddy currents. Self and mutual induction.

Chapter-7 Alternating Current

Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LC oscillations (qualitative treatment only), LCR series circuit, resonance; power in AC circuits. AC generator and transformer.

Deleted Topics

Unit/Chapter & Syllabus Reduced

Unit I Electrostatics

Chapter 1 : Electric Charges and Fields

- uniformly charged thin spherical shell (field inside and outside).

Unit II Current Electricity

Chapter 3 : Current Electricity

- Carbon resistors, colour code for carbon resistors; series and parallel combinations of resistors

Unit III Magnetic Effects of Current and Magnetism

Chapter 4 : Moving Charges and Magnetism

- Cyclotron.

Chapter 5 : Magnetism and Matter

- magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis, torque on a magnetic dipole (bar magnet) in a uniform magnetic field Para-, dia- and ferro - magnetic substances with examples. Electromagnets and factors affecting their strengths, permanent magnets.

Unit IV Electromagnetic Induction and Alternating Currents

Chapter 7 : Alternating Current

- power factor, wattless current.

CBSE Circular

Acad - 51/2021, 05 July 2021

About Latest Exam Scheme Term I & II

केन्द्रीय माध्यमिक शिक्षा बोर्ड

(शिक्षा मंत्रालय, भारत सरकार के अधीन एक स्वायत संगठन)

CENTRAL BOARD OF SECONDARY EDUCATION

(An Autonomous Organisation under the Ministryof Education, Govt. of India)

CBSE/DIR (ACAD)/2021 | **Date: July 05, 2021**
Circular No: Acad-51/2021

All the Heads of Schools affiliated to CBSE

Subject: Special Scheme of Assessment for Board Examination Classes X and XII for the Session 2021-22

COVID 19 pandemic caused almost all CBSE schools to function in a virtual mode for most part of the academic session of 2020-21. Due to the extreme risk associated with the conduct of Board examinations during the second wave in April 2021, CBSE had to cancel both its class X and XII Board examinations of the year 2021 and results are to be declared on the basis of a credible, reliable, flexible and valid alternative assessment policy. This, in turn, also necessitated deliberations over alternative ways to look at the learning objectives as well as the conduct of the Board Examinations for the academic session 2021-22 in case the situation remains unfeasible.

CBSE has also held stake holder consultations with Government schools as well as private independent schools from across the country especially schools from the remote rural areas and a majority of them have requested for the rationalization of the syllabus, similar to last year in view of reduced time permitted for organizing online classes. The Board has also considered the concerns regarding differential availability of electronic gadgets, connectivity and effectiveness of online teaching and other socio-economic issues specially with respect to students from economically weaker section and those residing in far flung areas of the country. In a survey conducted by CBSE, it was revealed that the rationalized syllabus notified for the session 2020-21 was effective for schools in covering the syllabus and helped learners in achieving learning objectives in a less stressful manner.

In the above backdrop and in line with the Board's continued focus on assessing stipulated learning outcomes by making the examinations competencies and core concepts based, student-centric, transparent, technology-driven, and having advance provision of alternatives for different future scenarios, the following schemes are introduced for the Academic Session for Class X and Class XII 2021-22.

2. **Special Scheme for 2021-22**

   A. **Academic session to be divided into 2 Terms with approximately 50% syllabus in each term:**
   The syllabus for the Academic session 2021-22 will be divided into 2 terms by following a systematic approach by looking into the interconnectivity of concepts and topics by the Subject Experts and the Board will conduct examinations at the end of each term on the basis of the bifurcated syllabus. This is done to increase the probability of having a Board conducted classes X and XII examinations at the end of the academic session.

   B. **The syllabus for the Board examination 2021-22 will be rationalized** similar to that of the last academic session to be notified in July 2021. For academic transactions, however, schools will follow the curriculum and syllabus released by the Board vide Circular no. F.1001/CBSE-Acad/Curriculum/2021 dated 31 March 2021. Schools will also use alternative academic calendar and inputs from the NCERT on transacting the curriculum.

   C. **Efforts will be made to make Internal Assessment/ Practical/ Project work more credible and valid** as per the guidelines and Moderation Policy to be announced by the Board to ensure fair distribution of marks.

3. **Details of Curriculum Transaction**

   - Schools will continue teaching in distance mode till the authorities permit in-person mode of teaching in schools.
   - **Classes IX-X: Internal Assessment** (throughout the year-irrespective of Term I and II) would include the *3 periodic tests, student enrichment, portfolio and practical work/ speaking listening activities/ project*.
   - **Classes XI-XII: Internal Assessment** (throughout the year-irrespective of Term I and II) would include end of topic or unit tests/ exploratory activities/ practicals/ projects.
   - Schools would create a student profile for all assessment undertaken over the year and retain the evidences in digital format.
   - CBSE will facilitate schools to upload marks of Internal Assessment on the CBSE IT platform.
   - Guidelines for Internal Assessment for all subjects will also be released along with the rationalized term wise divided syllabus for the session 2021-22.The Board would also provide additional resources like sample assessments, question banks, teacher training etc. for more reliable and valid internal assessments.

4. <u>Term I Examinations:</u>

- At the end of the first term, the Board will organize **Term I Examination** in a flexible schedule to be conducted between November-December 2021 with a window period of 4-8 weeks for schools situated in different parts of country and abroad. Dates for conduct of examinations will be notified subsequently.
- The Question Paper will have Multiple Choice Questions (MCQ) including case-based MCQs and MCQs on assertion-reasoning type. Duration of test will be **90 minutes** and it will cover only the rationalized syllabus of **Term I only** (i.e. approx. 50% of the entire syllabus).
- Question Papers will be sent by the CBSE to schools along with marking scheme.
- The exams will be conducted under the supervision of the External Center Superintendents and Observers appointed by CBSE.
- The responses of students will be captured on OMR sheets which, after scanning may be directly uploaded at CBSE portal or alternatively may be evaluated and marks obtained will be uploaded by the school on the very same day. The final direction in this regard will be conveyed to schools by the Examination Unit of the Board.
- Marks of the **Term I** Examination will contribute to the final overall score of students.

5. <u>Term II Examination/ Year-end Examination:</u>

- At the end of the second term, the Board would organize **Term II or Year-end Examination** based on the rationalized syllabus of Term II only (i.e. approximately 50% of the entire syllabus).
- This examination would be held around **March-April 2022** at the examination centres fixed by the Board.
- The paper will be of **2 hours duration** and have questions of different formats (case-based/ situation based, open ended- short answer/ long answer type).
- In case the situation is not conducive for normal descriptive examination **a 90 minute MCQ** based exam will be conducted at the end of the Term II also.
- Marks of the Term II Examination would contribute to the final overall score.

6. **Assessment / Examination as per different situations**

A. In case the situation of the pandemic improves and students are able to come to schools or centres for taking the exams.

Board would conduct Term I and Term II examinations at schools/centres and the theory marks will be distributed equally between the two exams.

B. In case the situation of the pandemic forces complete closure of schools during November-December 2021, but Term II exams are held at schools or centres.

Term I MCQ based examination would be done by students online/offline from home - in this case, the weightage of this exam for the final score would be reduced, and weightage of Term II exams will be increased for declaration of final result.

C. In case the situation of the pandemic forces complete closure of schools during March-April 2022, but Term I exams are held at schools or centres.

Results would be based on the performance of students on Term I MCQ based examination and internal assessments. The weightage of marks of Term I examination conducted by the Board will be increased to provide year end results of candidates.

D. In case the situation of the pandemic forces complete closure of schools and Board conducted Term I and II exams are taken by the candidates from home in the session 2021-22.

Results would be computed on the basis of the Internal Assessment/Practical/Project Work and Theory marks of Term-I and II exams taken by the candidate from home in Class X / XII subject to the moderation or other measures to ensure validity and reliability of the assessment.

In all the above cases, data analysis of marks of students will be undertaken to ensure the integrity of internal assessments and home based exams.

Dr. Joseph Emmanuel
Director (Academics)

01

Electric Charges and Fields

Quick Revision

1. **Charge** is the property associated with matter due to which it produces/experiences electric and magnetic effects. There are two types of charges namely **positive charge** and **negative charge .**

   Charge is a scalar quantity, it can be added and subtracted as a number. Its SI unit is coulomb and its dimensional formula is $[M^0 \; L^0 \; T A]$.

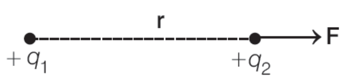
2. **Conservation of Electric Charge** During any process, the net electric charge of an isolated system remains constant, i.e. conserved. In simple words, charge can neither be created nor be destroyed.

3. **Quantisation of Charge** Charge exists in discrete amount rather than continuous value and hence it is quantised. Mathematically, charge on an object, $q = \pm ne$, where n is an integer and e is the electronic charge.

   where, $e = -1.6 \times 10^{-19}$ C.

4. **Coulomb's Law** It states that, the electrostatic force of attraction or repulsion acting between two stationary point charges is given by

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$



where, q_1 and q_2 are the magnitudes of stationary point charges and r is the distance of separation between them in air or vacuum.

Also, $\dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N-m}^2/\text{C}^2$

where, $\varepsilon_0 =$ permittivity of free space

$= 8.85419 \times 10^{-12} \text{ C}^2/\text{N-m}^2$

In vector form,

$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{|\mathbf{r}|^3} \mathbf{r} \text{ or } \mathbf{F} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{\mathbf{r}}$$

5. **Relative Permittivity** It is given by the ratio

$$\varepsilon_r = \frac{\varepsilon \text{(absolute permittivity of the medium)}}{\varepsilon_0}$$

where, ε_r is called **relative permittivity** of the medium with respect to vacuum. It is also denoted by K, which is called **dielectric constant** of the medium. It has no units.

$$\therefore \quad K \text{ or } \varepsilon_r = \frac{\varepsilon}{\varepsilon_0} = \frac{F_{\text{vacuum}}}{F_{\text{medium}}} \text{ and } \varepsilon = K \, \varepsilon_0$$

$$\mathbf{F}_{\text{medium}} = \frac{1}{4\pi\varepsilon_0} \frac{|q_1 q_2|}{K r^2}$$

6. **Principle of Superposition of Electrostatic Forces** states that, the net force experienced by a given charge particle q_0 due to a system of charged particles is equal to the vector sum of the forces exerted on it due to all the other charged particles of the system. i.e.

$$\mathbf{F}_0 = \mathbf{F}_{01} + \mathbf{F}_{02} + \mathbf{F}_{03} + \ldots + \mathbf{F}_{0n}$$

$$\mathbf{F}_0 = \frac{1}{4\pi\varepsilon_0} \left[\frac{q_1 q_0}{|\mathbf{r}_{10}|^3} \mathbf{r}_{10} + \frac{q_2 q_0}{|\mathbf{r}_{20}|^3} \mathbf{r}_{20} + \ldots + \frac{q_n q_0}{|\mathbf{r}_{n0}|^3} \mathbf{r}_{n0} \right]$$

where, $\mathbf{r}_{10} = \mathbf{r}_0 - \mathbf{r}_1$; $\mathbf{F}_{01}$ = force on q_0 due to q_1

Similarly, $\mathbf{r}_{n0} = \mathbf{r}_0 - \mathbf{r}_n$; $\mathbf{F}_{0n}$ = force on q_0 due to q_n

$$\therefore \qquad \mathbf{F}_0 = \frac{q_0}{4\pi\varepsilon_0}\left[\sum_{i=1}^{n} \frac{q_i}{|\mathbf{r}_{i0}|^3}\mathbf{r}_{i0}\right]$$

7. **Electrostatic Force due to Continuous Charge Distribution**

The region in which charges are closely spaced is said to have **continuous charge distribution**.

- Electric force at a point due to a **linear charge distribution** is given by

$$\mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_L \frac{\lambda\, dl}{\mathbf{r}_0^2}\hat{\mathbf{r}}_0$$

- Electric force at a point due to a **surface charge distribution** is given by

$$\mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_S \frac{\sigma\, dS}{\mathbf{r}_0^2}\hat{\mathbf{r}}_0$$

- Electric force at a point due to **volume charge distribution** is given by

$$\mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_V \frac{\rho\, dV}{\mathbf{r}_0^2}\hat{\mathbf{r}}_0$$

8. **Electric Field** due to a charge Q at a point in space may be defined as the force that a unit positive charge would experience, if placed at that point.

The charge which is producing the field is called **source charge** and the charge which experiences the effect of source charge is called **test charge.**

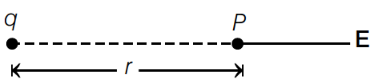
9. **Electric Field Intensity** A charge q_0 experiences an electric force $\mathbf{F}$, then electric field intensity at that point is given by

$$\mathbf{E} = \lim_{q_0 \to 0} \frac{\mathbf{F}}{q_0}$$

where, $q_0 \to 0$ means the test charge q_0 must be small.

It is a vector quantity and its SI unit is NC^{-1}.

10. **Electric Field Intensity due to a Point Charge**



Electric field intensity at P,

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{\mathbf{r}} \qquad \ldots\text{(i)}$$

The magnitude of the electric field at a point P is given by

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}$$

If $q > 0$, i.e. positive charge, $\mathbf{E}$ is directed away from source charge. On the other hand, if $q < 0$, i.e. negative charge, $\mathbf{E}$ is directed towards the source charge.

11. **Electric Field due to System of Charges**

If $\mathbf{E}$ is electric field at point P due to the system of charges, then by principle of superposition of electric fields, we get

$$\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2 + \mathbf{E}_3 + \cdots + \mathbf{E}_n = \sum_{i=1}^{n}\mathbf{E}_i$$

Using Eq. (i), we obtain

$$\mathbf{E} = \sum_{i=1}^{n}\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_i}{r_i^2}\hat{\mathbf{r}}_i$$

$$\text{or} \qquad \mathbf{E} = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i^2}\hat{\mathbf{r}}_i \qquad \ldots\text{(ii)}$$

12. **Electric Lines of Force** Imaginary curves drawn in electric field along which an unit positive test charge tends to move.

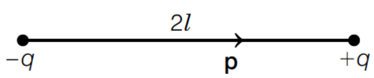
The tangent to a electric line of force at any point gives the direction of electric field at that point.

13. **Electric Dipole** Two point charges of equal magnitude and opposite nature separated by a small distance altogether forms an electric dipole.

14. **Electric Dipole Moment**

Magnitude of electric dipole moment is equal to product of magnitude of any charge q and separation between two charges $(2l)$.

$$\mathbf{p} = q(2\,l)$$



Direction of electric dipole moment is taken from negative charge $(-q)$ to positive charge $(+q)$. Its SI unit is C-m and it is a vector quantity.

15. **Electric field at any point on the axial line of electric dipole** is given by

$$E_{\text{axial}} = \frac{1}{4\pi\varepsilon_0} \frac{2pr}{(r^2 - l^2)^2}$$

When $l << r$, $E_{\text{axial}} = \dfrac{1}{4\pi\varepsilon_0} \dfrac{2p}{r^3}$

Direction of electric field at any point on axial line is along the direction of electric dipole moment.

16. **Electric field at any point on equatorial line** of electric dipole is given by

$$E_{\text{equatorial}} = \frac{1}{4\pi\varepsilon_0} \frac{p}{(r^2 + l^2)^{3/2}}$$

If $l << r$, $E_{\text{equatorial}} = \dfrac{1}{4\pi\varepsilon_0} \dfrac{p}{r^3}$

Direction of electric field intensity (E) due to a dipole at any point on equatorial line is parallel to dipole and opposite to the direction of dipole moment.

17. When $l << r$, $\dfrac{E_{\text{axial}}}{E_{\text{equatorial}}} = 2$

18. **Torque on an electric dipole placed in uniform electric field** is given by

$$\tau = \mathbf{p} \times \mathbf{E} \text{ or } \tau = pE \sin\theta$$

where, p = electric dipole moment,

E = electric field

and θ = angle between $\mathbf{p}$ and $\mathbf{E}$.

- Minimum torque experienced by electric dipole in electric field, when $\theta = 0°$ or π;
  $\Rightarrow \quad \tau = \tau_{\min} = 0$
- Maximum torque, when $\sin\theta = 1$
  $\Rightarrow \quad \theta = \pi/2, \ \tau = \tau_{\max} = pE$
- Dipole is in stable equilibrium in uniform electric field, when angle between $\mathbf{p}$ and $\mathbf{E}$ is 0° and unstable equilibrium, when angle $\theta = 180°$.

19. Net force on electric dipole placed in uniform electric field is zero.

20. **Work done in rotating the electric dipole from θ_1 to θ_2,** $W = pE(\cos\theta_1 - \cos\theta_2)$.

- Work done in rotating the dipole from the position of stable equilibrium to unstable equilibrium, i.e. when $\theta_1 = 0°$ and $\theta_2 = \pi$, $W = 2pE$.
- Work done in rotating the dipole from the position of stable equilibrium to the position in which dipole experiences maximum torque, i.e. when $\theta_1 = 0°$ and $\theta_2 = 90°$, $W = pE$.

21. **Potential energy of electric dipole**, when it makes an angle θ with the direction of electric field, $U = -pE\cos\theta = -\mathbf{p}\cdot\mathbf{E}$

22. The **electric flux** linked with a surface, when

- surface is held normal to the direction of uniform electric field $\mathbf{E}$, $\Delta\phi_E = E \cdot \Delta S$.
- area vector of surface makes an angle θ with the direction of uniform electric field $\mathbf{E}$,
  $$\Delta\phi_E = E\Delta S\cos\theta$$
  In vector form, $\Delta\phi_E = \mathbf{E}\cdot\Delta\mathbf{S}$

23. SI unit of electric flux is N-m^2/C and CGS unit is dyne-cm^2/stat-C.

24. **Gauss's Law** The total electric flux linked with closed surface S,

$$\phi_E = \oint \mathbf{E}\cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$$

where, q is the total charge enclosed by the closed gaussian (imaginary) surface.

25. **Electric field intensity due to an infinitely long thin straight charged wire at a distance** r,

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

where, λ is the uniform linear charge density.

26. **Electric field due to a thin infinite plane sheet** of charge with uniform surface charge density σ at any nearby point

$$E = \frac{\sigma}{2\varepsilon_0}$$

(for thin non-conducting plate)

and $E = \dfrac{\sigma}{\varepsilon_0}$ (for conducting plate)

27. **Electric field due to two equally and oppositely charged parallel plane sheets of charge at any point,**

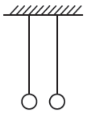
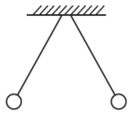
$E = \dfrac{\sigma}{\varepsilon_0}$ (between the two plates)

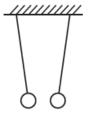
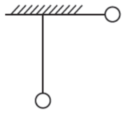
and $E = 0$ (outside the plates)

Objective Questions

Multiple Choice Questions

1. If a plastic rod rubbed with fur is made to touch two small pith balls suspended nearby, then which figure shows their final configuration?

(a) 
(b) 

(c) 
(d) 

2. A comb runs through one's dry hair attracts small bits of paper. This happens because

(a) comb is a good conductor
(b) paper is a good conductor
(c) the atoms in the paper get polarised by the charged comb
(d) the comb possesses magnetic properties

3. One metallic sphere A is given positive charge whereas another identical metallic sphere B of exactly same mass as of A is given equal amount of negative charge. Then,

(a) masses of A and B still remain equal
(b) mass of A increases
(c) mass of B decreases
(d) mass of B increases

4. In nature, the electric charge of any system is always equal to

(a) half integral multiple of the least amount of charge
(b) zero
(c) square of the least amount of charge
(d) integral multiple of the least amount of charge

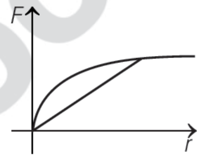
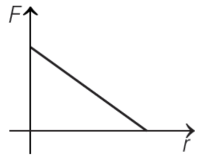
5. If the charge on the body is 1 nC, then how many electrons are present on the body?

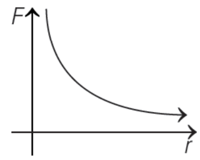
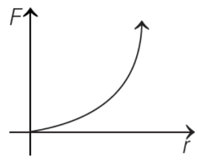
(a) 1.6×10^{-19} (b) 6.25×10^{9}
(c) 6.25×10^{27} (d) 6.25×10^{28}

6. Charge on a body is q_1 and it is used to charge another body by induction. Charge on second body is found to be q_2 after charging, then

(a) $\frac{q_1}{q_2} = 1$ (b) $\frac{q_1}{q_2} < 1$ (c) $\frac{q_1}{q_2} \le 1$ (d) $\frac{q_1}{q_2} \ge 1$

7. Force (F) between two charges varies with distance (r) between them as

(a) 
(b) 

(c) 
(d) 

8. The unit of electrical permittivity is

(a) $C^2/N\text{-}m^2$ (b) $N\text{-}m^2/C^2$
(c) N/C (d) $N\text{-}V/m^2$

9. The force of interaction between two charges $q_1 = 6\ \mu C$ and $q_2 = 2\ \mu C$ is 12 N. If charge $q = -2\ \mu C$ is added to each of the charges, then the new force of interaction is

(a) 2×10^{-7} N (b) zero
(c) 30 N (d) 2×10^{-3} N

10. A charge q is placed at the centre of the line joining two equal charges Q and Q. The system of the three charges will be in equilibrium, if q is equal to

(a) $-Q/2$ (b) $-Q/4$ (c) $+Q/4$ (d) $+Q/2$

11. Two point charges A and B, having charges $+Q$ and $-Q$ respectively, are placed at certain distance apart and force acting between them is F. If 25% charge of A is transferred to B, then force between the charges becomes

(a) $\frac{9F}{16}$ (b) $\frac{16F}{9}$
(c) $\frac{4F}{3}$ (d) F

12. Two particles of equal mass m and charge q are placed at a distance of 16 cm. They do not experience any force. The value of $\frac{q}{m}$ is

(a) l (b) $\sqrt{\frac{\pi\varepsilon_0}{G}}$
(c) $\sqrt{\frac{G}{4\pi\varepsilon_0}}$ (d) $\sqrt{4\pi\varepsilon_0 G}$

13. Two point charges placed at a certain distance r in air exert a force F on each other. Then, the distance r' at which these charges will exert the same force in a medium of dielectric constant K is given by

(a) r (b) r/K
(c) $r/\sqrt{K}$ (d) $r\sqrt{K}$

14. An object A has a charge of $-2\ \mu$C and the object B has a charge of $+6\ \mu$C. Which of the following is true?

(a) $F_{AB} = -3F_{BA}$ (b) $F_{AB} = -F_{BA}$
(c) $3F_{AB} = -F_{BA}$ (d) $F_{AB} = 4F_{BA}$

15. Electric charges of 1μC, -1μC and 2μC are placed in air at the corners A, B and C respectively of an equilateral triangle ABC having length of each side 10 cm.

The resultant force on the charge at C is

(a) 0.9 N (b) 1.8 N
(c) 2.7 N (d) 3.6 N

16. Each corner A and C has charge q_1 and on the each corner B and D, has charge $-q_2$ of a square $ABCD$ of side l.

Charge at A is in equilibrium, then the ratio $\frac{q_1}{q_2}$ will be

(a) 1 (b) $2\sqrt{2}$
(c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

17. The force between two charges 0.06 m apart is 5 N. If each charge is moved towards each other by 0.04 m, then the force between them will become

(a) 7.20 N (b) 11.25 N
(c) 22.50 N (d) 45.00 N

18. When the charge of a body becomes half, the electric field becomes

(a) half (b) twice
(c) thrice (d) No change

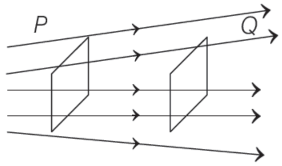
19. Forces exerted by a uniform electric field on an electron having mass m_e and proton of mass m_p are represented as F_e and F_p respectively are related as

(a) $F_p = F_e$ (b) $\frac{F_e}{F_p} = \frac{m_e}{m_p}$
(c) $\frac{F_e}{F_p} = \frac{m_p}{m_e}$ (d) $\frac{F_e}{F_p} = \frac{m_e^2}{m_p^2}$

20. A positively charged ball hangs from a silk thread. We put a positive test charge q_0 at a point and measure F / q_0, then it can be predicted that the electric field strength E

(a) $> F/q_0$
(b) $= \frac{F}{q}$
(c) $< F/q_0$
(d) Cannot be estimated

21. In the diagram shown below



(a) field strength at point P is less than field strength at point Q
(b) field strength at points P and Q are equal
(c) field is more strong at point P and less strong at point Q
(d) cannot be determined from the figure

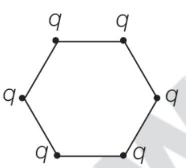
22. Two unlike charges of the same magnitude Q are placed at a distance d. The intensity of the electric field at the centre of the line joining the two charges, is

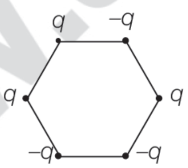
(a) zero (b) $\frac{8Q}{4\pi\varepsilon_0 d^2}$
(c) $\frac{6Q}{2\pi\varepsilon_0 d^2}$ (d) $\frac{4Q}{4\pi\varepsilon_0 d^2}$

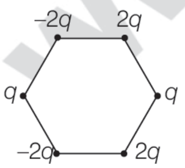
23. Two point charges $+8q$ and $-2q$ are located at $x = 0$ and $x = L$, respectively. The location of a point on the X-axis at which the net electric field due to these two point charges is zero, is

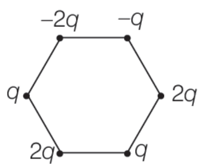
(a) $8L$ (b) $4L$ (c) $2L$ (d) $L/4$

24. Figure below show regular hexagons, with charges at the vertices. In which case, the electric field at the centre zero?

(a) 

(b) 

(c) 

(d) 

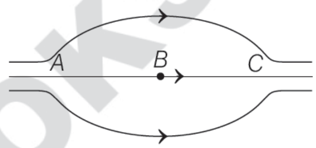
25. A charged particle is free to move in an electric field. It will travel

(a) always along a line of force
(b) along a line of force, if its initial velocity is zero
(c) along a line of force, if it has same initial velocity in the direction of an active angle with the line of force
(d) None of the above

26. Which of the following is not a property of electric field lines?

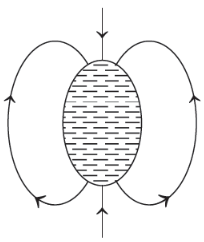
(a) Field lines are continuous curves without any breaks.
(b) Two field lines cannot cross each other.
(c) Field lines start at positive charges and end at negative charges.
(d) They does not form closed loops.

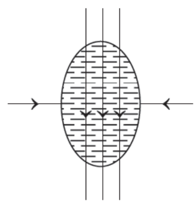
27. The figure shows some of the electric field lines corresponding to an electric field. The figure suggests

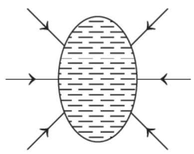


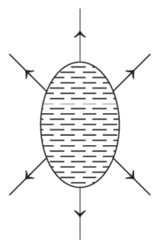
(a) $E_A > E_B > E_C$ (b) $E_A = E_B = E_C$
(c) $E_A = E_C > E_B$ (d) $E_A = E_C < E_B$

28. Find the correct diagram of electric lines of forces for negative charge.

(a) 

(b) 

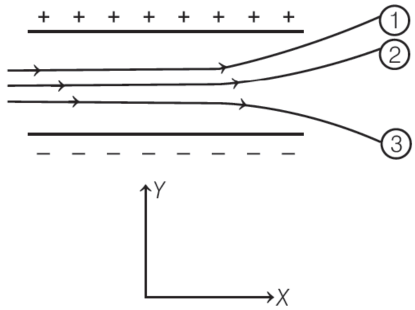
(c) 

(d) 

29. An electron enters uniform electric field maintained by parallel plates and of value E Vm^{-1} with a velocity v ms^{-1}, the plates are separated by a distance d metre, then acceleration of the electron in the field is

(a) $\frac{Ee}{m}$ (b) $\frac{-Ee}{m}$
(c) $\frac{Ee}{md}$ (d) $Ee\frac{d}{m}$

30. The given figure shows tracks of three charged particles in a uniform electrostatic field. Which particle has the highest charge to mass ratio?



(a) 1 (b) 2
(c) 3 (d) All are equal

31. Charges ± 20 nC are separated by 5 mm. Calculate the magnitude of dipole moment.

(a) 10 cm (b) 10^{-10} cm
(c) 2×10^{-6} cm (d) 10^2 cm

32. Electric charges $q, q, -2q$ are placed at the corners of an equilateral ΔABC of side l. The magnitude of electric dipole moment of the system is

(a) ql (b) $2ql$
(c) $\sqrt{3}ql$ (d) $4ql$

33. What is the angle between the electric dipole moment and the electric field strength due to it on the equatorial line?

(a) 0°
(b) 90°
(c) 180°
(d) None of the above

34. Let E_a be the electric field due to a dipole in its axial plane distant l and let E_q be the field in the equatorial plane distant l', then the relation between E_a and E_q will be

(a) $E_a = 4E_q$ (b) $E_q = 2E_a$
(c) $E_a = 2E_q$ (d) $E_q = 3E_a$

35. An electric dipole with dipole moment 4×10^{-9} C-m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^4 N/C. Calculate the magnitude of the torque acting on the dipole.

(a) 10^{-4} N-m (b) 4×10^{-4} N-m
(c) 10^{-5} N-m (d) 10×10^{-4} N-m

36. The dipole moment of a dipole in an uniform external field **E** is **p**, then the torque (τ) acting on the dipole is

(a) $\tau = \mathbf{p} \times \mathbf{E}$ (b) $\tau = \mathbf{p} \cdot \mathbf{E}$
(c) $\tau = 2(\mathbf{p} + \mathbf{E})$ (d) $\tau = (\mathbf{p} + \mathbf{E})$

37. An electric dipole is placed in an uniform electric field with the dipole axis making an angle θ with the direction of the electric field. The orientation of the dipole for stable equilibrium is

(a) $\pi/6$ (b) $\pi/3$
(c) 0 (d) $\pi/2$

38. Electric flux emanating through a surface element $d\mathbf{S} = 5\hat{\mathbf{i}}$ placed in an electric field $\mathbf{E} = 4\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + 4\hat{\mathbf{k}}$ is

(a) 10 units (b) 20 units
(c) 4 units (d) 16 units

39. What is the nature of gaussian surface involved in Gauss's law of electrostatics?

(a) Scalar (b) Electrical
(c) Magnetic (d) Vector

40. The gaussian surface for calculating the electric field due to a charge distribution is

(a) any surface near the charge distribution
(b) always a spherical surface
(c) a symmetrical closed surface containing the charge distribution, at every point of which electric field has a single fixed value
(d) None of the above

41. Flux coming out from a unit positive charge enclosed in air is

(a) ε_0 (b) $(\varepsilon_0)^{-1}$ (c) $(4\pi\varepsilon_0)^{-1}$ (d) $4\pi\varepsilon_0$

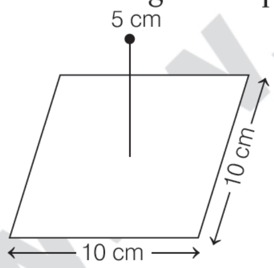
42. A charge q is placed at the point of intersection of body diagonals of a cube. The electric flux passing through any one of its face is ***(CBSE SQP 2020)***

(a) $\frac{q}{6\varepsilon_0}$ (b) $\frac{3q}{\varepsilon_0}$ (c) $\frac{6q}{\varepsilon_0}$ (d) $\frac{q}{3\varepsilon_0}$

43. The electric flux through a closed gaussian surface depends upon ***(CBSE Delhi 2020)***

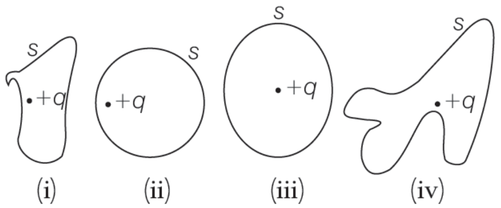
(a) net charge enclosed and permittivity of the medium
(b) net charge enclosed, permittivity of the medium and the size of the Gaussian surface
(c) net charge enclosed only
(d) permittivity of the medium only

44. A point charge $+10\,\mu$C is at a distance 5 cm directly above the centre of a square of side 10 cm, as shown in figure. What is the magnitude of the electric flux through the square?



(a) zero (b) $1.8\times10^{2}\ \text{Nm}^2\text{C}^{-1}$
(c) $1.8\times10^{4}\ \text{Nm}^2\text{C}^{-1}$ (d) $1.8\times10^{5}\ \text{Nm}^2\text{C}^{-1}$

45. The electric flux through the surface ***(NCERT Exemplar)***



(a) in Fig. (iv) is the largest
(b) in Fig. (iii) is the least
(c) in Fig. (ii) is same as Fig. (iii), but is smaller than Fig. (iv)
(d) is the same for all the figures

46. Eight dipoles of charges of magnitude e each are placed inside a cube. The total electric flux coming out of the cube will be

(a) $\frac{8e}{\varepsilon_0}$ (b) $\frac{16e}{\varepsilon_0}$
(c) $\frac{e}{\varepsilon_0}$ (d) zero

47. Two parallel infinite line charges $+\lambda$ and $-\lambda$ are placed with a separation distance R in free space. The net electric field exactly mid-way between the two line charges is

(a) zero (b) $\frac{2\lambda}{\pi\varepsilon_0 R}$
(c) $\frac{\lambda}{\pi\varepsilon_0 R}$ (d) $\frac{1}{2\pi\varepsilon_0 R}$

48. Two plates each having an area A are kept parallel to each other at a short distance d. They carry charges $+Q$ and $-Q$, respectively. The electric field in the space between the plates will be

(a) $Q/\varepsilon_0 A$ (b) $\varepsilon_0 A/Q\cdot d$
(c) $\varepsilon_0 Q/A\cdot d$ (d) $Q/2\varepsilon_0 A$

49. An infinite line charge produces a field of 18×10^4 N/C at 0.02 m. The linear charge density is

(a) 2×10^{-7} C/m
(b) 10^{-8} C/m
(c) 10^{7} C/m
(d) 10^{-4} C/m

50. A long cylindrical wire carries a positive charge of linear density λ. An electron $(-e, m)$ revolves around it in a circular path under the influence of the attractive electrostatic force.

The speed of electron is

(a) $v \propto r^0$ (b) $v \propto r^2$

(c) $v \propto \frac{1}{r}$ (d) $v \propto \frac{1}{r^2}$

51. Electrification by rubbing two bodies together is due to transference of .... from one body to the other.

(a) ions (b) electrons

(c) holes (d) positrons

52. The point charges each equal to 1C exert a force .... mutually when they are placed 1m apart in air.

(a) 10^8 N (b) 9×10^9 N

(c) 10^{10} N (d) 9×10^6 N

53. Two spheres have their surface charge densities in the ratio of 2 : 3 and their radii 3 : 2. The ratio of the charges on them is ....

(a) 3 : 2 (b) 4 : 2 (c) 2 : 3 (d) 2 : 4

54. An electric charge q is placed at one of the corners of a cube of side a. The electric flux on one of its faces will be ....

(a) $\frac{q}{a\varepsilon_0}$ (b) $\frac{q}{\varepsilon_0 a^2}$

(c) $\frac{q}{4\pi\varepsilon_0 a^2}$ (d) $\frac{q}{24\varepsilon_0}$

55. According the Gauss's theorem, electric field of an infinitely long straight wire is inversely proportional to ....

(a) distance

(b) diameter

(c) radius

(d) surface charge density

56. Which of the following statement(s) is/are incorrect regarding the point charge?

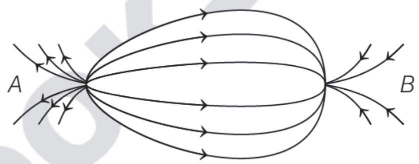
(a) The charge q on a body is always given by $q = ne$, where n is any integer, positive or negative.

(b) By convention, the charge on an electron is taken to be negative.

(c) The fact that electric charge is always an integral multiple of e is termed as quantisation of charge.

(d) The quantisation of charge was experimentally demonstrated by Newton in 1912.

57. The spatial distribution of the electric field due to charges (A, B) is shown in figure. Which one of the following statements is correct?



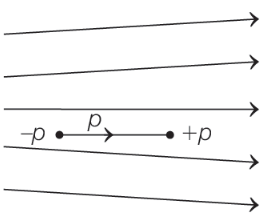
(a) A is positive and B is negative $|A| > |B|$.

(b) A is negative and B is positive $|A| = |B|$.

(c) Both are positive but $A > B$.

(d) Both are negative but $A > B$.

58. Figure shows electric field lines in which an electric dipole P is placed as shown. Which of the following statements is correct? ***(NCERT Exemplar)***



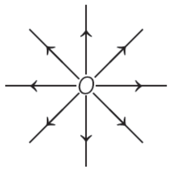
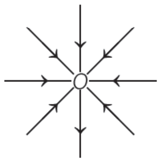
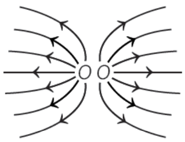
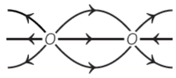
(a) The dipole will not experience any force.

(b) The dipole will experience a force towards right.

(c) The dipole will experience a force towards left.

(d) The dipole will experience a force upwards.

59. Match the Column I (electric lines of force) with Column II (types of charge) and select the correct answer from the codes given below.

	Column I		Column II
A.		p.	A pair of equal and opposite charges
B.		q.	A pair of positive charges
C.		r.	A single positive charge
D.		s.	A single negative charge

Codes

	A	B	C	D		A	B	C	D
(a)	p	q	r	s	(b)	r	q	p	s
(c)	r	s	p	q	(d)	r	s	q	p

60. Match the Column I (type of body) with Column II (electric field) and select the correct answer from the codes given below.

	Column I		Column II
A.	Infinite plane sheet of charge	p.	$\frac{\lambda}{2\pi\varepsilon_0 r}$
B.	Infinite plane sheet of uniform thickness	q.	$\frac{\sigma}{2\varepsilon_0}$
C.	Infinitely long uniformly charged straight wire	r.	$\frac{\sigma}{\varepsilon_0}$

Codes

	A	B	C
(a)	q	r	p
(b)	r	q	p
(c)	p	r	q
(d)	q	p	r

Assertion/Reasoning MCQs

*For question numbers 61 to 76, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

61. **Assertion** When we produce charge q_1 on a body by rubbing it against another body which gets a charge q_2 in the process, then $q_1 + q_2 = 0$.

Reason Charge on an isolated system remains constant.

62. **Assertion** When charges are shared between any two bodies, then no charge is really lost but some loss of energy does occur.

Reason Some energy disappears in the form of heat, sparking, etc.

63. **Assertion** At macroscopic level, quantisation of charge has no practical consequence and can be ignored.

Reason $1\,\mu C$ charge contains 10^{15} times electronic charge e approximately.

64. **Assertion** Mass of a body does not decreases, when it is negatively charged.

Reason Charging is not mainly due to transfer of electrons.

65. **Assertion** The gravitational force is the dominating force in the universe.

Reason The coulomb force is weaker than the gravitational force.

66. **Assertion** At the centre of the line joining two equal and opposite charges, $E = 0$.

Reason At the centre of the line joining two equal and similar charge, $E \neq 0$.

67. **Assertion** A point charge is brought in an electric field, then electric field at a nearby point may increase or decrease.

Reason The electric field is dependent on the nature of charge.

68. **Assertion** Acceleration of charged particle in non-uniform electric field does not depend on velocity of charged particle.

Reason Charge is an invariant quantity.

69. **Assertion** Electric lines of force cross each other.

Reason Electric field at a point does not superimposes to give one resultant electric field.

70. **Assertion** Away from a charge field lines gets weaker and density of field lines is less, resulting in well separated lines.

Reason Only a finite number of lines can be drawn from a charge.

71. **Assertion** On going away from a small electric dipole, electric field decreases.

Reason Electric field is inversely proportional to square of distance from an electric dipole.

72. **Assertion** In a non-uniform electric field, a dipole will have translatory as well as rotatory motion.

Reason In non-uniform electric field, dipole experiences torque only.

(CBSE SQP 2021)

73. **Assertion** If a dipole is enclosed by a surface, then according to Gauss's law, electric flux linked with it will be zero.

Reason The charge enclosed by a surface is zero.

74. **Assertion** In a region, where uniform electric field exists, the net charge within volume of any size is zero.

Reason The electric flux within any closed surface in a region of uniform electric field is zero.

75. **Assertion** Upon displacement of charges within a closed surface, E at any point on the surface does change.

Reason The flux crossing through a closed surface is dependent on the location of charge within the surface.

76. **Assertion** E in outside vicinity of a conductor depends only on the local charge density σ and it is independent of the other charges present anywhere on the conductor.

Reason E in outside vicinity of a conductor is given by $\frac{2\sigma}{\varepsilon_0}$.

Case Based MCQs

Direction *Answer the questions from 77-81 on the following case.*

Electric Charges

The physical property of matter that causes it to experience a force when placed in an electromagnetic field is called electric charge. Electric charge is a characteristic that accompanies fundamental particles, wherever they exist.

The process of charging a neutral body by bringing a charged body nearby it without making contact between the two bodies is known as charging by induction.

Figures given below are showing the sequential steps of charging a conductor permanently by using the process of charging by induction.

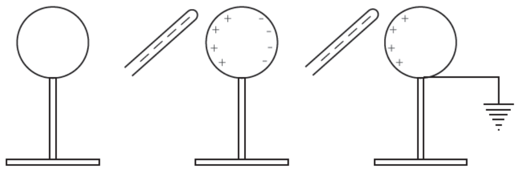


Fig. (a) Fig. (b) Fig. (c)

77. When a glass rod is rubbed with silk, it becomes positively charged because

(a) protons are transferred to silk
(b) electrons are transferred to silk
(c) protons are added to it
(d) electrons are added to it

78. Which of the following method can be used to charge a metal sphere positively without touching it?

(a) Connect the positive terminal of battery and float the other end of battery.
(b) Rub it with a piece of fur.
(c) Bring a negatively charged rod near it and touch it to ground for some time.
(d) Rub it with a piece of silk.

79. We have two bodies with charge q_1 and q_2 on them, then $q_1 + q_2 = 0$, signify,

(a) q_1 and q_2 are equal charges
(b) q_1 and q_2 are equal charges with opposite signs
(c) q_1 and q_2 are equal charges with same signs
(d) q_1 and q_2 are not equal charges

80. If an object is positively charged, theoretically, the mass of the object

(a) increases slightly by a factor of 9.11×10^{-31} kg
(b) decreases slightly by a factor of 9.11×10^{-31} kg
(c) remains the same
(d) may increase of decrease

81. The value of charge on a body which carries 30 excess electrons is

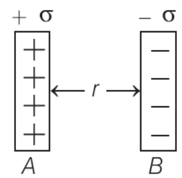
(a) -4.8×10^{-18} C (b) 4.8×10^{-18} C
(c) -4×10^{-18} C (d) 48×10^{-18} C

Direction *Answer the questions from 82-86 on the following case.*

Charge between Parallel Plates

Surface charge density is defined as the charge per unit surface area of surface charge distribution. i.e. $\sigma = \dfrac{dq}{dS}$

Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs having magnitude of 17.0×10^{-22} Cm^{-2} as shown below



The intensity of electric field at a point is

$$E = \frac{\sigma}{\varepsilon_0}$$

where, ε_0 = permittivity of free space.

82. **E** in the outer region of the first plate is

(a) 17×10^{-22} N/C (b) 1.5×10^{-15} N/C
(c) 1.9×10^{-10} N/C (d) zero

83. **E** in the outer region of the second plate is

(a) 17×10^{-22} N/C (b) 1.5×10^{-15} N/C
(c) 1.9×10^{-10} N/C (d) zero

84. **E** between the plates is

(a) 17×10^{-22} N/C (b) 1.5×10^{-15} N/C
(c) 1.9×10^{-10} N/C (d) zero

85. The ratio of **E** from right side of plate **B** at distances 2 cm and 4 cm, respectively is

(a) 1 : 2 (b) 2 : 1
(c) 1 : 1 (d) $1 : \sqrt{2}$

86. In order to estimate the electric field due to a thin finite plane metal plate, the gaussian surface considered is

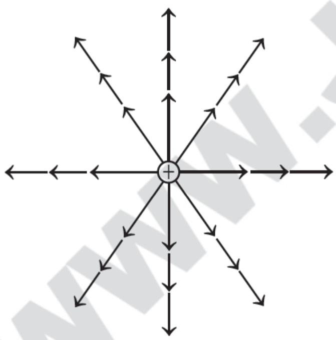
(a) spherical (b) cylindrical
(c) straight line (d) None of these

Direction *Answer the questions from 87-91 on the following case.*

Electric Field Lines

An electric field line in general is a curve drawn in such a way that the tangent to it at each point is in the direction of the electric field at that point. A field line is a space curve, i.e. a curve in three dimensions.

Electric field lines are thus used to pictorially map the electric field around a charge or a configuration of charges.



Field lines showing electric field of a point charge

The density of field lines is more near the charge. Away from the charge, the field is weak, so the density of field lines is less.

87. Electric field lines always move from

(a) higher to lower potential
(b) lower to higher potential
(c) infinity to zero potential
(d) None of the above

88. Choose the correct statement regarding electric lines of force.

(a) Emerges from negative charge and meet at positive charge.
(b) A closely spaced region of electric lines of force represents strong electric field.
(c) Representation of field lines for a point charge and a solid sphere are same.
(d) They have physical nature.

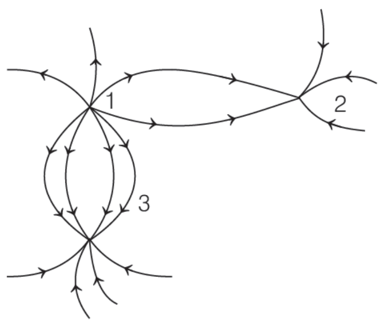
89. The spacing between two electric field lines indicates its

(a) charge
(b) position
(c) strength
(d) None of the above

90. The electric field lines of a negatively charged particle are

(a) radial and outwards
(b) radial and inwards
(c) circular and anticlockwise
(d) circular and clockwise

91. What kind of charges are of 1, 2 and 3?



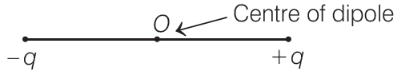
(a) $q_1 = -\text{ve}, q_2 = -\text{ve}, q_3 = -\text{ve}$
(b) $q_1 = -\text{ve}, q_2 = +\text{ve}, q_3 = +\text{ve}$
(c) $q_1 = +\text{ve}, q_2 = -\text{ve}, q_3 = -\text{ve}$
(d) $q_1 = +\text{ve}, q_2 = +\text{ve}, q_3 = +\text{ve}$

Direction *Answer the questions from 92-96 on the following case.*

Electric Dipole

An electric dipole is a pair of point charges with equal magnitude and opposite in sign separated by a very small distance.

The mid-point of locations of $-q$ and q is called the centre of the dipole.



The strength of an electric dipole is measured by a vector quantity known as **electric dipole moment** (p) which is the product of the charge (q) and separation between the charges ($2l$).

In most molecules, the centres of positive charges and of negative charges lie at the same place, hence their dipole moment is zero. e.g. CO_2, CH_4. However, they develop a dipole moment when an electric field is applied. But some molecules have permanent dipole moment. e.g. H_2O which are called **polar molecules.** If the centre of mass of positive charges coincides with the centre of mass of negative charges, the molecule behaves as a **non-polar molecule**.

92. Dipoles in an electric field undergo
(a) magnetism (b) electromagnetism
(c) magnetisation (d) polarisation

93. Calculate the distance (in units) between two charges of 4C each forming a dipole with a dipole moment of 6 units.
(a) 1 (b) 1.5 (c) 2 (d) 2.5

94. The dipole moment of two equal charges 2C separated by a distance of 2cm is
(a) 0.02 C-m
(b) 0.04 C-m
(c) 0.06 C-m
(d) 0.08 C-m

95. Dipole moments are used to calculate the
(a) electric field intensity
(b) polarisation pattern
(c) strength of the dipole in the field
(d) susceptibility

96. What are the dimensions of dipole moment?
(a) [ILT] (b) $[ILT^{-1}]$
(c) $[IL^2T]$ (d) [IT]

Direction *Answer the questions from 97-101 on the following case.*

Faraday Cage

A Faraday cage or Faraday shield is an enclosure made of a conducting material. The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero.

These Faraday cages act as big hollow conductors. You can put things to shield them from electrical fields. Any electrical shocks the cage receives, pass harmlessly around the outside of the cage. ***(CBSE SQP 2021)***

97. Which of the following material can be used to make a Faraday cage?
(a) Plastic (b) Glass
(c) Copper (d) Wood

98. Example of a real-world Faraday cage is
(a) car (b) plastic box
(c) lightning rod (d) metal rod

99. What is the electrical force inside a Faraday cage, when it is struck by lightning?
(a) The same as the lightning
(b) Half that of the lightning
(c) Zero
(d) A quarter of the lightning

100. An isolated point charge $+q$ is placed inside the Faraday cage. Its surface must have charge equal to

(a) zero (b) $+q$
(c) $-q$ (d) $+2q$

101. A point charge of 2C is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be

(a) 1.9×10^5 N-m^2/C, entering the surface
(b) 1.9×10^5 N-m^2/C, leaving the surface
(c) 2.01×10^5 N-m^2/C, leaving the surface
(d) 2.01×10^5 N-m^2/C, entering the surface

ANSWERS

Multiple Choice Questions

1. (b)	2. (c)	3. (d)	4. (d)	5. (b)	6. (d)	7. (c)	8. (a)	9. (b)	10. (b)
11. (a)	12. (d)	13. (c)	14. (b)	15. (b)	16. (b)	17. (b)	18. (a)	19. (a)	20. (a)
21. (c)	22. (b)	23. (c)	24. (a)	25. (b)	26. (d)	27. (c)	28. (c)	29. (b)	30. (c)
31. (b)	32. (c)	33. (c)	34. (c)	35. (a)	36. (a)	37. (c)	38. (b)	39. (d)	40. (c)
41. (b)	42. (a)	43. (a)	44. (d)	45. (d)	46 (d)	47. (b)	48. (a)	49 (a)	50 (a)
51. (b)	52. (b)	53. (a)	54. (d)	55. (a)	56 (d)	57. (a)	58. (c)	59 (d)	60 (a)

Assertion/Reasoning MCQs

61. (a)	62. (b)	63. (c)	64. (d)	65. (c)	66. (d)	67. (a)	68. (b)	69. (d)	70. (c)
71. (c)	72. (c)	73. (a)	74. (a)	75. (d)	76. (d)				

Case Based MCQs

77. (b)	78. (c)	79. (b)	80. (b)	81. (a)	82. (d)	83. (d)	84. (c)	85. (c)	86. (b)
87. (a)	88. (b)	89. (c)	90. (b)	91. (c)	92. (d)	93 (b)	94 (b)	95 (b)	96. (a)
97. (c)	98. (a)	99. (c)	100. (c)	101. (c)					

SOLUTIONS

1. When a plastic rod is rubbed with fur, an electric charge is developed in it. On touching this rod to pith balls, these charges are transferred from the rod to the pith ball in contact. As the charge on both pith balls is same, so they repel each other with same force.

Thus, figure given in option (b) shows final configuration.

2. When a comb runs through one's dry hair, then comb gets charged. If it then comes close to the paper, it induces opposite charges on paper. The field due to the charges on comb, polarises the atoms in the paper. Finally due to the induction of charges, it attracts the paper.

3. When a body is negatively charged, more electrons are given to it, so its mass increases. So, this is the reason due to which mass of sphere B increases when it is given equal amount of negative charge.

4. If the charge of an electron is taken as elementary unit, i.e. quanta of charge, so the charge on any body will be some integral multiple of the charge on electron, i.e. $q = ne$, where $n = 1, 2, 3, \ldots$ and e is the elementary charge on electron.

5. Given, $q = 1\text{ nC} = 1 \times 1 \times 10^{-9}$ C

$(\because 1\text{ nC} = 1 \times 10^{-9}\text{C})$

and $\quad e = 1.6 \times 10^{-19}$C

From the property of quantisation charge,

$$q = ne$$

$$n = \frac{q}{e} = \frac{1 \times 10^{-9}}{1.6 \times 10^{-19}}$$

$$= 0.625 \times 10^{-9} \times 10^{19}$$

$$= 0.625 \times 10^{10}$$

$$= 6.25 \times 10^{9}$$

6. After charging by induction, the charge on the other (second) body will be less or almost equal to the charge on the first body.

Numerically, $\quad q_1 \geq q_2 \;\Rightarrow\; \dfrac{q_1}{q_2} \geq 1$

7. According to Coulomb's law, force between two point charges, i.e. $F \propto \dfrac{1}{r^2}$. Therefore, the graph between F and r will be as shown in option (c).

8. From Coulomb's law,

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

$\therefore$ Electrical permittivity,

$$\varepsilon_0 = \frac{q_1 q_2}{4\pi \times F \times r^2} = \frac{\text{C} \times \text{C}}{\text{N} \times \text{m}^2}$$

$\therefore$ Unit of electrical permittivity $= \text{C}^2/\text{N-m}^2$

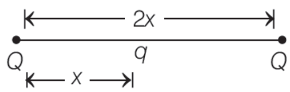
9. Here, $q_1' = (6-2)\,\mu\text{C}$

and $\quad q_2' = (2-2)\,\mu\text{C}$

New force, $F = kq_1'q_2'/r^2$

$$= \frac{1}{4\pi\varepsilon_0} \frac{(6-2)\,(2-2)}{r^2} \times 10^{-12} = 0$$

10. Consider the situation shown in figure below



For the system to be in equilibrium,

$$\frac{1}{4\pi\varepsilon_0} \frac{Q\,q}{x^2} = \frac{-1}{4\pi\varepsilon_0} \frac{Q^2}{(2x)^2}$$

$$\Rightarrow \qquad q = -Q/4$$

11. The force between two point charges A and B having charges $+Q$ and $-Q$ respectively, placed at a certain distance r,

$$F = \frac{k\,Q_A Q_B}{r^2} = \frac{kQ\,(-Q)}{r^2} = -\frac{kQ^2}{r^2} \qquad \ldots\text{(i)}$$

where, k = constant $= \dfrac{1}{4\pi\varepsilon_0}$

When 25% charge of A is transferred to B, then new amount of charge on A and B respectively becomes

$$Q'_A = \frac{75}{100}(Q_A) = \frac{3}{4}Q$$

$$Q'_B = \left(\frac{25}{100}Q_A + Q_B\right)$$

$$= \left(\frac{1}{4}Q - Q\right) = \frac{-3}{4}Q$$

So, the force between the two charges now becomes,

$$F' = \frac{kQ'_A Q'_B}{r^2} = \frac{k\left(\frac{3}{4}Q\right)\left(-\frac{3}{4}Q\right)}{r^2}$$

$$= \frac{-9kQ^2}{16r^2} = \frac{9}{16}F \qquad \text{[from Eq. (i)]}$$

Thus, the new force between the charges is (9/16) times the initial force between the charges.

12. They will not experience any force, if $|\mathbf{F}_G| = |\mathbf{F}_e|$

$$\Rightarrow \quad \frac{Gm^2}{r^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{r^2}$$

$$\Rightarrow \quad \frac{q^2}{m^2} = 4\pi\varepsilon_0 G$$

$$\Rightarrow \quad q/m = \sqrt{4\pi\varepsilon_0 G}$$

13. Force exerted between two point charges in air,

$$F = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}$$

So, force exerted between two point charges in a medium of dielectric constant K,

$$F' = \frac{q_1q_2}{4\pi\varepsilon_0 K(r')^2}$$

where, r' is the distance.

Given, $F = F'$

$$\Rightarrow \quad \frac{q_1q_2}{4\pi\varepsilon_0 r^2} = \frac{q_1q_2}{4\pi\varepsilon_0 K(r')^2}$$

$$\Rightarrow \quad \frac{1}{r^2} = \frac{1}{K(r')^2}$$

$$\Rightarrow \quad r^2 = K(r')^2$$

$$\Rightarrow \quad r = \sqrt{K}\ r'$$

$$\therefore \quad r' = \frac{r}{\sqrt{K}}$$

14. Vector form of Coulomb's law states that "$\mathbf{F}_{AB}$ and $\mathbf{F}_{BA}$ are equal and opposite".

Since, $\hat{\mathbf{r}}_{AB}$ and $\hat{\mathbf{r}}_{BA}$ are unit vectors pointing in opposite direction, we have

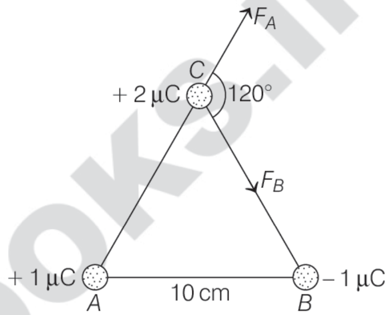
$$\hat{\mathbf{r}}_{AB} = -\hat{\mathbf{r}}_{BA}$$

Therefore, equations of force is given by

$$\mathbf{F}_{AB} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}(\hat{\mathbf{r}}_{AB})$$

$$= -\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}\hat{\mathbf{r}}_{BA} = -\mathbf{F}_{BA}$$

15. Let F_A = force on charge at C due to charge at A,



$$\therefore \quad F_A = 9\times10^9 \times \frac{10^{-6}\times2\times10^{-6}}{(10\times10^{-2})^2} = 1.8\ \text{N}$$

Similarly, F_B = force on point C due to charge at B

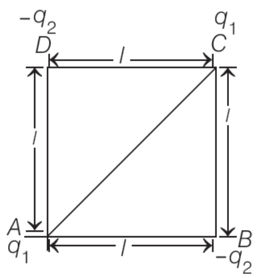
$$\therefore \quad F_B = 9\times10^9 \times \frac{10^{-6}\times2\times10^{-6}}{(10\times10^{-2})^2} = 1.8\ \text{N}$$

$\therefore$ Net force on C,

$$F_{\text{net}} = \sqrt{(F_A)^2 + (F_B)^2 + 2F_AF_B\cos120^\circ}$$

$$= \sqrt{(1.8)^2 + (1.8)^2 + 2(1.8)(1.8)(-1/2)} = 1.8\ \text{N}$$

16.



For equilibrium condition,

$$F_{DA} + F_{AB} + F_{AC} = 0$$

$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1(-q_2)}{l^2}\cos45^\circ + \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1(-q_2)}{l^2}\cos45^\circ + \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1^2}{(\sqrt{2}l)^2} = 0$$

$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1^2}{2l^2}=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{l^2}2\cos 45^\circ$$

$$\Rightarrow \quad \frac{q_1}{q_2}=4\cos 45^\circ$$

$$\Rightarrow \quad \frac{q_1}{q_2}=4\times\frac{1}{\sqrt{2}}=2\sqrt{2}$$

17. According to Coulomb's law,

$$F\propto\frac{1}{r^2}\Rightarrow\frac{F_1}{F_2}=\left(\frac{r_2}{r_1}\right)^2$$

$$\Rightarrow \quad \frac{5}{F_2}=\left(\frac{0.04}{0.06}\right)^2$$

$\therefore$ Force between two charges, $F_2=11.25$ N

18. Electric field is directly proportional to the charge.

So, when the charge of the body becomes half, then the electric field becomes half.

19. The force (F) on charge q due to electric field strength E is $F=qE$

Charge on electron and proton is same.

Here, E is uniform, hence $F_p=F_e$.

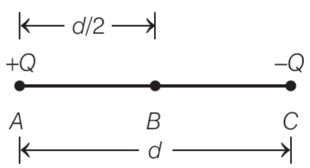
20. Due to presence of test charge q_0 infront of positively charged ball, there would be a redistribution of charge on the ball. In the redistribution of charge, there will be less charge on front half surface and more charge on the back half surface.

As a result, the net force F between ball and charge will decrease, i.e. the electric field is decreased. Thus, actual electric field will be greater than F/q_0.

i.e. $\quad E'>\frac{F}{q_0}$

21. Area of points P and Q are equal but more lines pass through area at point P. So, field is more stronger at point P as compared to point Q.

22. Two equal and opposite charges are placed at a distance d.



Electric field at centre (B) due to $+Q$ charge,

$$E_1=\frac{1}{4\pi\varepsilon_0}\frac{Q}{(d/2)^2}$$

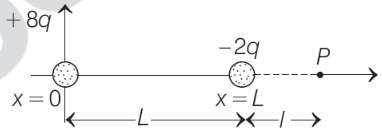
Similarly, electric field due to $-Q$ charge,

$$E_2=\frac{1}{4\pi\varepsilon_0}\frac{Q}{(d/2)^2}$$

Therefore, net electric field at point,

$$E=E_1+E_2$$
$$=\frac{1}{4\pi\varepsilon_0}\frac{4Q}{d^2}+\frac{1}{4\pi\varepsilon_0}\frac{4Q}{d^2}$$
$$=\frac{1}{4\pi\varepsilon_0}\frac{8Q}{d^2}$$

23. The net electric field will be zero at a point outside the charges and near the charges which is smaller in magnitude.



Suppose electric field is zero at P as shown in the above figure.

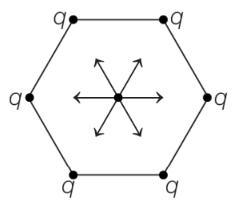
Hence, at P,

$$K\frac{8q}{(L+l)^2}=\frac{K\cdot(2q)}{l^2}$$

$$\Rightarrow \quad l=L$$

So, distance of P from origin is $L+L=2L$.

24. In the option (a), the fields due to charges at the opposite corners cancel each other. So, in this case, net electric field at the centre will be zero.



25. Electric field E points along the tangent to the lines of force. If initial velocity is zero, then due to the force, it moves in the direction of E.

26. Electric field lines does not form continuous closed loops and they have continuous curves without any break.

27. At point A and C, electric field lines are dense and equally spaced, so $E_A = E_C$. While at B, they are far apart.

$\therefore \quad E_A = E_C > E_B$

28. For negative charge, direction of electric field lines will be always towards the charge. i.e. it starts from positive charges and end at negative charges. Hence, option (c) is correct.

29. Here, electric force is given by

$$F = -eE \quad \ldots\text{(i)}$$

But, we know that, $F = ma$ ...(ii)

From Eqs. (i) and (ii),

$$ma = -eE$$

$$\Rightarrow \quad a = \frac{-eE}{m}$$

where, a is acceleration of electron, E is the electric field and m is the mass of electron.

30. As, the deflection in the path of a charged particle is directly proportional to the charge/mass ratio.

i.e. $\quad y \propto \frac{q}{m}$

Here, the deflection in particle 3 is maximum, so the charge to mass ratio of particle 3 is maximum.

31. Given, $q_1 = q_2 = \pm 20$ nC

$$= \pm 20 \times 10^{-9}\,\text{C}$$

Distance $= 2a = 5$ mm

$$= 5 \times 10^{-3}\ \text{m}$$

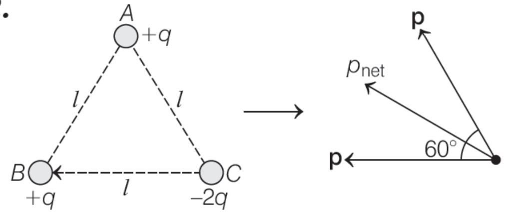
Dipole moment,

$$p = q(2a)$$

$$= 20 \times 10^{-9} \times 5 \times 10^{-3}$$

$$= 10^{-10}\ \text{cm}$$

32.



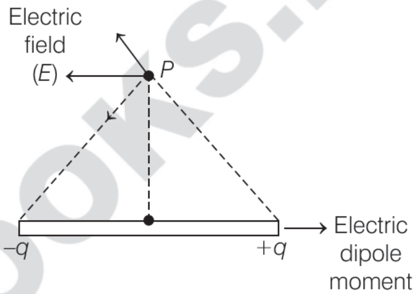
Net dipole moment,

$$p_{\text{net}} = \sqrt{p^2 + p^2 + 2pp\cos 60^\circ}$$

$$= \sqrt{3}p \qquad \left(\because \cos 60^\circ = \frac{1}{2}\right)$$

$$= \sqrt{3}\,ql \qquad (\because p = ql)$$

33. The electric dipole moment is a vector quantity whose direction is along the axis of the dipole pointing from the negative charge to the positive charge.



The direction of electric field is from positive charge to negative charge. As it is clear from the figure, the direction of electric field intensity at a point on the equatorial line of the dipole is opposite to the direction of dipole moment.

Hence, angle between them is 180°.

34. Intensity of electric field at a point on the axis of dipole is given by

$$E_a = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3}\ \text{N/C} \quad \ldots\text{(i)}$$

where, p is dipole moment.

Intensity of electric field at a point on the equatorial line of dipole is given by

$$E_q = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p}{r^3}\ \text{N/C} \quad \ldots\text{(ii)}$$

Dividing Eq. (i) by Eq. (ii), we get

$$\frac{E_a}{E_q} = \frac{2}{1}$$

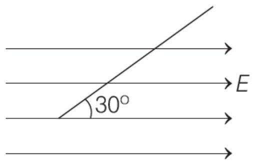
$$\Rightarrow \quad E_a = 2E_q$$

35. Given, dipole moment,

$$p = 4 \times 10^{-9}\ \text{C-m}$$

Electric field, $E = 5 \times 10^4$ N/C

Angle between electric field and the dipole moment, $\theta = 30°$



Torque applied on a dipole in the electric field, $\tau = \mathbf{p} \times \mathbf{E} = pE \sin\theta$

$$= 4 \times 10^{-9} \times 5 \times 10^{4} \times \sin 30° = \frac{20 \times 10^{-5}}{2}$$

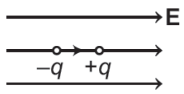
$$= 10^{-4} \text{N-m}$$

The direction of torque is perpendicular to both electric field and dipole moment.

36. Torque (τ) acting on the dipole in an uniform external field $\mathbf{E}$,

$$\tau = \text{Either force} \times \text{Perpendicular distance}$$
$$= qE \times 2a \sin\theta = (q \times 2a) \times E \sin\theta$$
$$= pE \sin\theta \text{ or } \tau = \mathbf{p} \times \mathbf{E}$$

37. For stable equilibrium, the angle θ should be zero.



$$\tau = pE \sin\theta = 0$$

38. Given, $\mathbf{E} = 4\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + 4\hat{\mathbf{k}}$

and $d\mathbf{S} = 5\hat{\mathbf{i}}$

$\therefore \quad \phi = \mathbf{E} \cdot d\mathbf{S}$

$\Rightarrow \quad \phi = (4\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + 4\hat{\mathbf{k}}) \cdot (5\hat{\mathbf{i}})$

$\phi = 20$ units

39. The Gauss's law in electrostatic given a relation between electric flux through any closed hypothetical surface (called a gaussian surface) and the charge enclosed by the surface.

So, the nature of gaussian surface is vector.

40. The gaussian surface for calculating the electric field due to a charge distribution is a symmetrical closed surface containing the charge distribution, at every point of which electric field has a single fixed value.

41. Given that, charge, $q = +1$ C

From Gauss's law, corresponding flux,

$$\phi = \frac{q}{\varepsilon_0}$$

$$\Rightarrow \quad \phi = \frac{1}{\varepsilon_0}$$

$$\Rightarrow \quad \phi = (\varepsilon_0)^{-1}$$

42. From Gauss's law, total outward flux through a closed surface, $\phi = \frac{q}{\varepsilon_0}$

where, q = charge enclosed by the gaussian surface.

As, the surface is cubical, it has 6 faces.

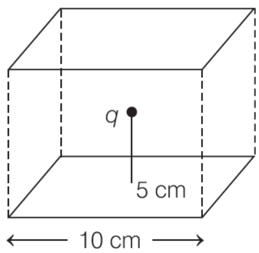
Flux through one face, $\phi' = \frac{\phi}{6} = \frac{q}{6\varepsilon_0}$

43. According to the Gauss's law, the net electric flux through any closed Gaussian surface is equal to the net charge enclosed by it divided by permittivity of the medium.

Mathematically, $\phi_E = \oint_S \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$

This law is true for any closed surface, no matter what is its shape or size.

44. A point charge + 10 μC is at a distance 5 cm above the centre of a square of side 10 cm is shown below



Given, $q = 10\ \mu\text{C}$

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

According to Gauss's theorem, the total flux enclosed,

$$\phi = \frac{q}{\varepsilon_0} \quad \text{...(i)}$$

The flux enclosed by one face of square is (1/6) of total flux (because the cube has six square shaped faces).

The flux linked with each face,

$$\phi' = \frac{\phi}{6} = \frac{1}{6} \cdot \frac{q}{\varepsilon_0} \quad \text{[from Eq. (i)]}$$

$$\phi' = \frac{1}{6} \times \frac{10 \times 10^{-6}}{8.854 \times 10^{-12}}$$
$$= 1.88 \times 10^{5} \text{ Nm}^2\text{C}^{-1}$$

Thus, the flux linked with the square is $1.88 \times 10^5 \text{ Nm}^2\text{C}^{-1}$.

45. Gauss's law of electrostatics states that, the total of the electric flux out of a closed surface is equal to the charge enclosed (Q) divided by the permittivity of free space ε_0.

$\therefore$ Electric flux $= \dfrac{Q}{\varepsilon_0}$

Thus, electric flux through a surface does not depend on the shape, size and area of a surface but it depends on the number of charges enclosed by the surface.

So, here in this question, all the figures same electric flux as all of them has single positive charge.

46. Net charge of one dipole $= -e + e = 0$

Net charges of 8 dipoles $= 8 \times 0 = 0$

$\therefore$ Net charge inside cube, $q = 0$

By Gauss's law, total flux emerging from surface, $\phi = \dfrac{q}{\varepsilon_0} = \dfrac{0}{\varepsilon_0} = 0$

47. According to Gauss's theorem, $\phi = \dfrac{q}{\varepsilon_0}$

or $E \cdot 2\pi R \times l = \dfrac{\lambda}{\varepsilon_0}$

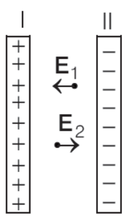
Electric field in mid-way due to both lines,

$$E = \frac{1}{2\pi} \frac{\lambda}{\varepsilon_0 (R/2)} \times 2$$

$$\Rightarrow \quad E = \frac{2\lambda}{\pi\varepsilon_0 R}$$

48. Electric field intensity due to first plate,

$$E_1 = \sigma / 2\varepsilon_0$$



Similarly, electric field intensity due to second plate,

$$E_2 = \sigma / 2\varepsilon_0$$

$\because$ E_1 and E_2 has same direction.

$\therefore$ Resultant field,

$$E = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

$\because$ Surface density of charge on any charged surface is

$$\sigma = Q / A$$

$\therefore$ Electric field, $E = Q / \varepsilon_0 A$

49. Linear charge density,

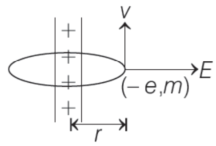
$$E = \frac{\lambda}{2\pi\varepsilon_0 r} = \frac{2\lambda}{4\pi\varepsilon_0 r}$$

or $$\lambda = \frac{E \times 4\pi\varepsilon_0 r}{2}$$

$$= 18 \times 10^4 \times \frac{1}{9 \times 10^9} \times \frac{0.02}{2}$$

$$= 2 \times 10^{-7} \text{ C/m}$$

50. Electric field at perpendicular distance r,



$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Electric force on electron, $F = eE$

To move in circular path, necessary centripetal force is provided by electric force.

$$F_c = \frac{mv^2}{r} = eE = \frac{e\lambda}{2\pi\varepsilon_0 r}$$

Hence, speed of the electron,

$$v = \sqrt{\frac{e\lambda}{2\pi\varepsilon_0 m}} \Rightarrow v \propto r^0$$

51. Electrification by rubbing two bodies together is due to the transference of electrons from one body to the other.

52. According to Coulomb's law, $F = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

Here, $q_1 = q_2 = 1$ C

$r = 1$m

$$\Rightarrow \quad F = \frac{k \times 1 \times 1}{(1)^2}$$

$$F = k = 9 \times 10^9 \text{ N}$$

53. As, $\sigma = \dfrac{q}{4\pi r}$

where, σ is surface charge density and r is radius.

$\Rightarrow \qquad \sigma \propto q / r^2$

Given, $\dfrac{\sigma_1}{\sigma_2} = \dfrac{2}{3}$

$$\frac{r_1}{r_2} = \frac{3}{2}$$

So, $\dfrac{q_1}{q_2} = \dfrac{2}{3} \times \left(\dfrac{3}{2}\right)^2 = \dfrac{3}{2}$

54. When charge q is placed at one corner, the flux through each of the three faces melting at this corner will be zero, as E is parallel to these faces. One-eight of the flux emerging from charge q passes through the remaining three faces, so the flux through each such face is

$$\phi_E = \frac{1}{3} \times \frac{1}{8} \frac{q}{\varepsilon_0} = \frac{1}{24} \cdot \frac{q}{\varepsilon_0}$$

55. Electric field, $E = \dfrac{\lambda}{2\pi\varepsilon_0 r}$

$\Rightarrow \qquad E \propto \dfrac{\lambda}{r}$

So, E is directly proportional to surface charge density and inversely to the distance between the wire and the point at which E is obtained.

56. The statement (d) is incorrect and it can be corrected as,

The quantisation of charge was first suggested by the experimental laws of electrolysis discovered by English expermentalist Faraday. It was experimentally demonstrated by Millikan in 1912. Rest statements are correct.

57. Electric lines of force usually start (i.e. diverge out) from positive charge and end (i.e. converge) on negative charge or extends to infinity. Thus, A is positive charge and B is negative charge. Also, density of lines at A is more than that at B, i.e. $|A| > |B|$.

58. The space between the electric field lines is increasing, here from left to right and due to which, the strength of electric field decreases with increase in the space between the electric field lines.

As a result, force on charges also decreases from left to right.

Thus, the force on charge $-q$ is greater than force on charge $+q$ which in turn will experience a force towards left.

59 A. Electric lines of forces emerge from a single positive charge and goes to infinity.

B. Electric lines of forces enter into a single negative charge coming from infinity.

C. Electric lines of forces are repelled away, when they are produced by the pair of positive charge.

D. The electric line of forces produced by a pair of equal and opposite charges.

Hence, A $\to$ r, B $\to$ s, C $\to$ q, D $\to$ p.

60. A. Electric field due to a infinite sheet of charge is $E = \dfrac{\sigma}{2\varepsilon_0}$.

B. Electric field due to infinitely long uniformly charged straight wire is $E = \dfrac{\lambda}{2\pi\varepsilon_0 r}$.

C. Electric field due to non infinite plane sheet of uniform thickness is $E = \dfrac{\sigma}{\varepsilon_0}$.

Hence, A $\to$ q, B $\to$ r, C $\to$ p.

61. When we produce charge q_1 on a body by rubbing it against another body which gets a charge q_2 in the process, then q_1 and q_2 both are equal in magnitude but opposite in polarities. Hence, $q_1 + q_2 = 0$.

This is because charge on an isolated system remains constant.

Therefore, both A and R are true and R is the correct explanation of A.

62. Charge is always conserved but energy is lost in the form of heat.

Therefore, both A and R are true but R is not the correct explanation of A.

63. At macroscopic level, we deal with charges of order $1\,\mu C = 10^{-6}$C, which has $\dfrac{10^{-6}}{1.6 \times 10^{-19}}$

$= 0.625 \times 10^{13} = 10^{13}$ charges.

Addition of a few hundred of e charges do not make any physically observable effect on attraction or repulsion, so quantisation can be ignored.

Therefore, A is true but R is false.

64. A body acquire charge by the transfer of electrons. When a body acquire negative charge by gaining more electrons, then its mass increases slightly from its neutral state.

Therefore, A is false and R is also false.

65. Gravitational force is the dominating and weakest force in universe. Also, coulomb force >> gravitational force.

Therefore, A is true but R is false.

66. For two equal and opposite charges, electric field will be non-zero. As, the field has some finite value. On the other hand, electric field for two equal and similar charges will become zero as the direction of field between them is in opposite directions. So, net field is zero.

Therefore, A is false and R is also false.

67. Electric field at the nearby point will be resultant of existing field and field due to the point charge. It may increase or decrease, if the charge is positive or negative depending on the position of the point with respect to the point charge.

Therefore, both A and R are true and R is the correct explanation of A.

68. Acceleration of a charged particle in non-uniform electric field is $a = \frac{F}{m} = \frac{q}{m}$

As, E changes, a also changes, but it does not depends on the velocity of the charged particle.

Charge is invariant quantity.

Therefore, both A and R are true but R is not correct explanation of A.

69. If electric lines of force cross each other, then the electric field at the point of intersection will have two direction simultaneously which is not possible physically.

The resultant electric field at any point is equal to the vector sum of electric fields at that point due to various charges.

Therefore, A is false and R is also false.

70. Electric field due to a point charge is $E = \frac{kq}{r^2}$.

So, if the distance from the field increases, it's strength decreases and it will be less dense.

Also, there are infinite number of electric lines of forces that can be drawn from the charge.

Therefore, A is true but R is false.

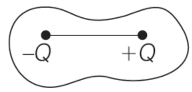
71. In case of an electric dipole, electric field, decreases rapidly, as $E \propto 1/r^3$.

Therefore, A is true but R is false.

72. In a non-uniform electric field, dipole experiences both force as well as torque. Thus, it will have translatory as well as rotatory motion.

Therefore, A is true but R is false.

73. If a dipole is enclosed by a surface as shown in figure



Then, $Q_{\text{enclosed}} = 0$

$\therefore \quad \phi = 0$ (from Gauss's law)

Therefore, both A and R are true and R is the correct explanation of A.

74. Flux, $\phi_{\text{net}} = \frac{q_{\text{in}}}{\varepsilon_0}$

If a closed body, is placed in an electric field (either uniform or non-uniform), total flux linked with it will be zero.

i.e. $\phi_{\text{net}} = 0 \Rightarrow q_{\text{in}} = 0$

Therefore, both A and R are true and R is the correct explanation of A.

75. Due to displacement of charge within a closed surface, E at any point may change. But net flux crossing the surface will not change. The flux crossing through a closed surface is independent of the location of charge within the surface, as it is same everywhere on its surface.

Therefore, A is false and R is also false.

76. E in outside vicinity of conductor surface depends on all the charges present in the space and its expression is $E = \frac{\sigma}{\varepsilon_0}$.

Therefore, A is false and R is also false.

77. On rubbing, the negative charge electrons of the glass rod get transferred to the silk cloth and hence it becomes positively charged.

78. Charging without touching is possible only by induction. So, if a negatively charged rod is placed near the sphere, then it attracts positive charge inside the sphere towards its side and the negative charge to other side, which is earthed by connecting with ground.

79. $q_1 + q_2 = 0$, signifies that the net charge on the system is zero.

This is possible only, if q_1 and q_2 are equal but opposite in signs.

80. When an object is positively charged, it loses some of its electrons. The mass of an electron is 9.11×10^{-31} kg, so the positively charged body loses electrons and its mass decreases by a factor of 9.11×10^{-31} kg.

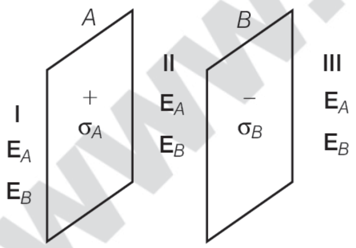
81. Given, $n = 30$

Charge of electron, $e = -1.6 \times 10^{-19}$ C

$\therefore$ Charge on body, $q = ne = 30 \times 1.6 \times 10^{-19}$

$= -4.8 \times 10^{-18}$ C

82. There are two plates A and B having surface charge densities $\sigma_A = 17.0 \times 10^{-22}$ C/m^2 on A and $\sigma_B = -17.0 \times 10^{-22}$ C/m^2 on B, respectively.



According to Gauss's theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.

$$\mathbf{E}_\text{I} = \mathbf{E}_A + \mathbf{E}_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

83. The electric field in region III is also zero.

$$\mathbf{E}_\text{III} = \mathbf{E}_A + \mathbf{E}_B$$
$$= \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

84. In region II, the electric field

$$\mathbf{E}_\text{II} = \mathbf{E}_A - \mathbf{E}_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$
$$= \frac{\sigma}{\varepsilon_0} = \frac{\sigma_A \text{ or } \sigma_B}{\varepsilon_0}$$
$$= \frac{17.0 \times 10^{-22}}{8.85 \times 10^{-12}}$$
$$E = 1.92 \times 10^{-10} \text{ NC}^{-1}$$

85. Since, electric field due to an infinite.-plane sheet of charge does not depend on the distance of observation point from the plane sheet of charge. So, for the given distances, the ratio of **E** will be 1 : 1.

86. In order to estimate the electric field due to a thin finite plane metal plate, we take a cylindrical cross-sectional area A and length $2r$ as the gaussian surface.

87. In electrostatics, the direction of field lines is always from higher potential to lower potential.

88. The electric field in a region is strong when the electric lines of force in that region are closely spaced.

89. The spacing between field lines indicates its strength. So, if the field lines are closely spaced, the intensity of the electric field will be more.

90. The electric field lines emerge from a positive charge and appears to meet at a negative charge. So, for a negative charge, the electric field lines will be radial and directed inwards.

91. Electric field lines start from positive charge and end at negative charge.

So, $q_1 = +\text{ve}$, $q_2 = -\text{ ve}$ and $q_3 = -\text{ ve}$

92. Dipoles in an electric field undergo polarisation. It is the process of alignment of dipole moments in accordance with the electric field.

93. Given, $q = 4$ C and $p = 6$ units

$$\therefore p = q \times d \Rightarrow d = \frac{p}{q} = \frac{6}{4} = 1.5 \text{ units}$$

94. Given, $q = 2$ C

$d = 2$ cm $= 0.02$ m

$\therefore p = q \times d = 2 \times 0.02 = 0.04$ C-m

95. Dipoles are used to calculate the polarisation patterns based on the applied field.

96. Dipole moment, $p = q \times d$

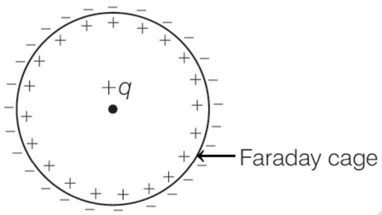
$$[\mathrm{m}] = [\mathrm{ITL}]$$

97. As Faraday cage is made of a conducting material and copper is the only conducting material in given option. So, copper is used to make a Faraday cage.

98. Car is an example of a real-world Faraday cage, as it is made of metal body, which is a hollow conduction and can shield from electric shock.

99. As the electric field inside a Faraday cage is zero, so no electric force will act inside it is zero.

100. The charge distribution is as shown



So, the charge on the surface must be $-q$.

101. As, the cube is a closed surface, so according to Gauss's law, the electric flux or number of electric field lines passing through its surface normally are

$$\phi_E = \frac{q}{\varepsilon_0}$$

Here, $q = 2$ C

and ε_0 = permittivity of free space,

$$= 8.85 \times 10^{-12}\ \mathrm{C^2N^{-1}m^{-2}}$$

$$\therefore \quad \phi_E = \frac{2}{8.85 \times 10^{-12}} = 0.226 \times 10^{12}\ \mathrm{N\text{-}m^2/C}$$

It is leaving the surface of cube.

The 2 C charge is impractical value.

So, if we take, $q = 2\,\mu$C, then

$$\phi_E = \frac{2 \times 10^{-6}}{8.85 \times 10^{-12}}$$

$$= 0.225 \times 10^{6}\ \mathrm{N\text{-}m^2/C}$$

or $\quad 2.26 \times 10^{5}\ \mathrm{N\text{-}m^2/C}$

which is close to $2.0 \times 10^{5}\ \mathrm{Nm^2/C}$ as in option (c).

02

Electrostatic Potential and Capacitance

Quick Revision

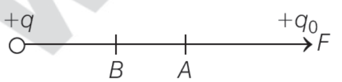
1. **Electric Potential** or electrostatic potential at any point in the region of electric field is equal to the amount of work done in bringing the unit positive test charge from infinity to that point, against electrostatic forces without acceleration.

   Electric potential $(V) = \dfrac{\text{Work done }(W)}{\text{Charge }(q)}$

   Its SI unit is volt (V) and $1\,\text{V} = 1\,\text{J/C}$.

   It is a scalar quantity.

2. **Electric Potential Difference** The difference of potential between two points in an electric field is defined as the amount of work done in moving an unit positive test charge from one point to the other against electrostatic force without any acceleration, i.e. the difference of electric potentials of two points in the electric field.



$$V_B - V_A = \frac{W_{AB}}{q_0}$$

   where, W_{AB} is work done in taking charge q_0 from point A to point B against electrostatic force, i.e. work done by external force.

3. **Electric potential due to a point charge q** at any point P lying at a distance r from it, is given by

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

4. The potential at a point due to a positive charge is **positive** while due to **negative** charge is negative.

5. When a positive charge is placed in an electric field, it experiences a force which drives it from points of higher potential to points of lower potential. On the other hand, a negative charge experiences a force driving it from lower to higher potential.

6. Electric potential at any point P due to a system of **n-point charges** $q_1, q_2, \ldots, q_n$ whose position vectors are $\mathbf{r}_1, \mathbf{r}_2, \ldots, \mathbf{r}_n$, respectively is given by

$$V = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{|\mathbf{r} - \mathbf{r}_i|}$$

   where, $\mathbf{r}$ is the position vector of point P w.r.t. the origin.

7. The electric potential on the perpendicular bisector, i.e. in equatorial plane due to an electric dipole is zero.

8. Electric potential due to an electric dipole at any point P whose position vector is $\mathbf{r}$ with respect to mid-point of dipole is given by

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2} \quad\text{or}\quad V = \frac{1}{4\pi\varepsilon_0}\frac{\mathbf{p}\cdot\hat{\mathbf{r}}}{|\mathbf{r}|^2}$$

   where, θ is the angle between $\hat{\mathbf{r}}$ and $\mathbf{p}$.

9. Electric potential due to a thin charged spherical shell carrying charge q and radius R, respectively at any point lying
   - inside the shell, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$ for $r < R$
   - on the surface of shell, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$ for $r = R$
   - outside the shell, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ for $r > R$

   where, r is the distance of the point from the centre of the shell.
10. **Equipotential surface** is a surface which has same electrostatic potential at every point on it.
11. **Relationship between electric field and potential gradient**
$$\mathbf{E} = -\frac{dV}{dr} \quad \text{or} \quad \mathbf{E} = E_x\hat{\mathbf{i}} + E_y\hat{\mathbf{j}} + E_z\hat{\mathbf{k}}$$
i.e. $E_x = -\frac{\partial V}{\partial x}, E_y = -\frac{\partial V}{\partial y}, E_z = -\frac{\partial V}{\partial z}$

   where, negative sign indicates that the direction of electric field is from higher potential to lower potential.
12. **Electrostatic potential energy** of a system of point charges is defined as the total amount of work done in bringing the different charges to their respective positions from infinitely large mutual separations.
   - Electrostatic potential energy of a system of two point charges
$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$
   - Electrostatic potential energy of a system of n point charges, $U = \frac{1}{4\pi\varepsilon_0}\sum_{\substack{j=1}}^{n}\sum_{\substack{i=1}}^{n}\frac{q_j q_i}{r_{ji}}$
   $j \neq i$ and $ij = ji$
13. **Potential energy** of a single charge in external field is $q \cdot V(\mathbf{r})$, where $V(\mathbf{r})$ is the potential at the point due to external electric field $\mathbf{E}$.
14. **Potential energy of a system** of two charges in an external field,
$$U = q_1 \cdot V(\mathbf{r}_1) + q_2 \cdot V(\mathbf{r}_2) + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$$
   where, q_1, q_2 = two point charges at position vectors $\mathbf{r}_1$ and $\mathbf{r}_2$ respectively,

   $V(\mathbf{r}_1)$ = potential at r_1 due to the external field and $V(\mathbf{r}_2)$ = potential at r_2 due to the external field.
15. Potential energy of the dipole placed in external field $\mathbf{E}$, so that it rotates from angle θ_1 to θ_2 with respect to $\mathbf{E}$,
$$U(\theta) = pE(\cos\theta_1 - \cos\theta_2)$$
16. **Capacitor** is a device which is used to store electrostatic potential energy or charge. It comprises of two conductors separated by an insulating medium.
17. **Capacitance of a Conductor** If charge q is given to a pair of insulated conductors, then it leads to increase its electric potential by V, then
$$q \propto V \Rightarrow q = CV$$
   where, C is known as capacitance of conductor. It is the ability of capacitor to store the charge and energy.

   The capacitance depends on shape, size and geometry of conductor, nature of surrounding medium and presence of other conductor in its surrounding.

   SI unit of capacitance is farad (F). Farad is very large unit of capacitance, so smaller units is usually taken such as,
$$1\mu F = 10^{-6} F, 1\, nF = 10^{-9} F \text{ and } 1\, pF = 10^{-12} F.$$
18. Capacitance of an isolated spherical conductor of radius r is given by $C = 4\pi\varepsilon_0 r$.
19. **Dielectric Constant** If C_{vacuum} be the capacity of a condensor (capacitor) with vacuum or air between its plates and $C_{\text{dielectric}}$ be the capacity with dielectric between the plates, the dielectric constant K is defined as
$$K = \frac{C_{\text{dielectric}}}{C_{\text{vacuum}}}$$
   Dielectric constant is also known as **specific inductive capacity** of the dielectric or relative permittivity.
20. **Parallel plate capacitor** comprises of two metal plates of area A and separated by distance d. The capacitance of air filled parallel plate capacitor is given by

$$C_0 = \frac{\varepsilon_0 A}{d}$$

When a dielectric medium of dielectric constant K is filled fully between the plates of the capacitor, then capacitance,

$$C = \frac{KA\varepsilon_0}{d}$$

21. The capacitance of a parallel plate capacitor partially filled with a dielectric medium of dielectric constant K is given by

$$C = \frac{\varepsilon_0 A}{(d - t + t/K)}$$

where, t = thickness of dielectric medium.

22. **Series Combination of Capacitors**
    - Charge on each capacitor is same for any value of capacitance and equals to the charge across the combination.
    - The potential difference across the combination is equal to the algebraic sum of potential difference across each capacitor.

      i.e. $$V = V_1 + V_2 + V_3$$
    - The potential divides across capacitors in inverse ratio of their capacitances, i.e.

      $$V_1 : V_2 : V_3 = \frac{1}{C_1} : \frac{1}{C_2} : \frac{1}{C_3}$$
    - The equivalent capacitance is given by

      $$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$
    - If n identical capacitors are connected in series combination, then equivalent capacitance, $C_s = \frac{C_{eq}}{n}$

23. **Parallel Combination of Capacitors**
    - The potential difference across each capacitor is same for any value of capacitance and equals to the potential difference across the combination.
    - The total charge on the combination is equal to the algebraic sum of charges on each capacitor,

      i.e. $$q = q_1 + q_2 + q_3$$
    - The equivalent capacitance C_{eq} is given by

      $$C_{eq} = C_1 + C_2 + C_3$$
    - The total charge on the capacitor is divided in the ratio of their capacitances, i.e.

      $$q \propto C_{eq}$$

      $$\Rightarrow \quad q_1 : q_2 : q_3 = C_1 : C_2 : C_3$$
    - The equivalent capacitance of n-identical capacitors connected in parallel combination, $C_p = nC_{eq}$

24. **Electrostatic energy stored** in a capacitor (parallel plate) is given by

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

$$= \frac{1}{2}qV = \frac{q^2}{2C}$$

where, q = charge on capacitor,
C = capacitance
and V = potential difference across capacitor.

25. **Energy Density** The energy stored per unit volume of space in a capacitor is known as energy density. It is given by $U_E = \frac{1}{2}\varepsilon_0 E^2$, where E is the electric field intensity between two plates of capacitor.

Objective Questions

Multiple Choice Questions

1. Unit of electrical potential is

(a) J/C (b) J-C
(c) V-m (d) J/C-m

2. 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 upto the point is

(a) V/q (b) Vq
(c) $V+q$ (d) V

3. If 100 J of work has to be done in moving an electric charge of 4 C from a place, where potential is -10 V to another place where potential is V volt, find the value of V.

(a) 5 V (b) 10 V
(c) 25 V (d) 15 V

4. The electric potential due to point charge 3nC at distance of 9 cm is

(a) 270 V (b) 3 V
(c) 300 V (d) 30 V

5. A metallic hollow spherical surface of radius 5 cm is charged such that the potential on its surface is 10 V. The potential at the centre is

(a) zero
(b) 10 V
(c) same as at a point 5 cm away from the surface
(d) same as at a point 25 cm away from the surface

6. The potential of a large liquid drop when eight liquid drops are combined is 20 V , then the potential of each single drop was

(a) 10 V (b) 7.5 V
(c) 5 V (d) 2.5 V

7. The potential of an electric dipole varies with distance r as

(a) $\frac{1}{r}$ (b) $\frac{1}{r^3}$ (c) $\frac{1}{r^4}$ (d) $\frac{1}{r^2}$

8. The potential in the equatorial plane of a dipole having dipole moment p is

(a) infinite (b) zero
(c) maximum (d) equal to p

9. Two equal and opposite charges ($+q$ and $-q$) are situated at a distance x from each other. The value of potential at very far point will depend upon

(a) only on q (b) only on x
(c) on $q \cdot x$ (d) on $\frac{q}{x}$

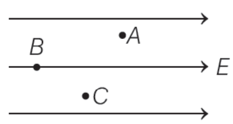
10. In a region of constant potential, ***(NCERT Exemplar)***

(a) the electric field is uniform
(b) the electric field is zero
(c) there can be no charge inside the region
(d) the electric field shall necessarily change, if a charge is placed outside the region

11. A positively charged particle is released from rest in an uniform electric field. The electric potential energy of the charge ***(NCERT Exemplar)***

(a) remains a constant because the electric field is uniform
(b) increases because the charge moves along the electric field
(c) decreases because the charge moves along the electric field
(d) decreases because the charge moves opposite to the electric field

12. A, B and C are three points in a uniform electric field, the electric potential is



(a) maximum at A
(b) maximum at B
(c) maximum at C
(d) same at all the three points A, B and C

13. Equipotential surfaces at a great distance from a collection of charges whose total sum is not zero are approximately ***(NCERT Exemplar)***

(a) spheres (b) planes
(c) paraboloids (d) ellipsoids

14. The electrostatic potential energy between proton and electron separated by a distance of 1 Å is

(a) 13.6 eV (b) 27.2 eV
(c) – 14.4 eV (d) 1.44 eV

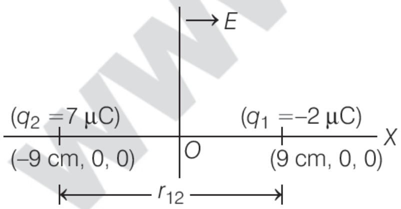
15. The electric potential of earth is taken to be zero, because earth is a good

(a) insulator (b) conductor
(c) semiconductor (d) dielectric

16. Suppose a system of two charges as shown below placed in an external electric field

$E = A\left(\frac{1}{r^2}\right)$, where $A = 9 \times 10^5\ \text{C/m}^2$

What would be the electrostatic energy of the configuration?



(a) 49 J (b) 49.3 J
(c) –49.3 J (d) 45 J

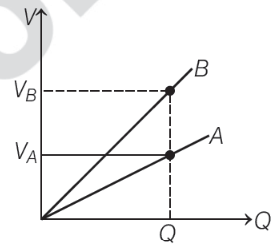
17. An electric field of 1000 V/m is applied to an electric dipole at angle of 45°. The value of electric dipole moment is 10^{-29} C-m. What is the potential energy of the electric dipole?

(a) -9×10^{-20} J (b) -10×10^{-29} J
(c) -20×10^{-18} J (d) -7×10^{-25} J

18. If a conductor has a potential $V \neq 0$ and there are no charges anywhere else outside, then

(a) there must be charges on the surface or inside itself
(b) there cannot be any charge in the body of the conductor
(c) there must be charges only on the surface
(d) there must be charges inside the surface

19. The graph shows the variation of voltage V across the plates of two capacitors A and B *versus* increase of charge Q stored in them. Which of the capacitors has higher capacitance?



(a) Capacitor A
(b) Capacitor B
(c) Both have same capacitance
(d) None of the above

20. Two plates of capacitors are at potentials – 10 V and + 30 V. If the separation between the plates be 2m, the electric field between them is

(a) 20 V/m (b) 10 V/m
(c) 50 V/m (d) 30 V/m

21. The electric potential difference between two parallel plates is 2000 V. If the plates are separated by 2 mm, then what is the magnitude of electrostatic force on a charge of 4×10^{-6} C located mid-way between the plates?

(a) 4 N (b) 6 N
(c) 8 N (d) 1.5×10^{-6} N

22. A parallel plate capacitor has circular plates of radius 8 cm and plate separation 1 mm.

The charge on the plates, if potential difference of 100 V applied is

(a) 1.78×10^{-8} C
(b) 1.78×10^{-5} C
(c) 4.3×10^{4} C
(d) 2×10^{-9} C

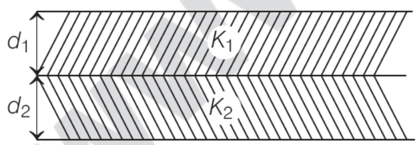
23. An air capacitor is charged with an amount of charge q and dipped into an oil tank. If the oil is pumped out, the electric field between the plates of capacitor will

(a) increase
(b) decrease
(c) remain the same
(d) becomes zero

24. A parallel plate air capacitor has a capacitance 18 μF. If the distance between the plates is tripled and a dielectric medium is introduced, the capacitance becomes 72 μF. The dielectric constant of the medium is

(a) 4 (b) 9
(c) 12 (d) 2

25. A parallel plate capacitor is made of two dielectric blocks in series. Effective dielectric constant K is **(NCERT Exemplar)**



(a) $\dfrac{K_1d_1 + K_2d_2}{d_1 + d_2}$ (b) $\dfrac{K_1d_1 + K_2d_2}{K_1 + K_2}$

(c) $\dfrac{K_1K_2(d_1 + d_2)}{(K_1d_2 + K_2d_1)}$ (d) $\dfrac{2K_1K_2}{K_1 + K_2}$

26. Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance of the combination will be

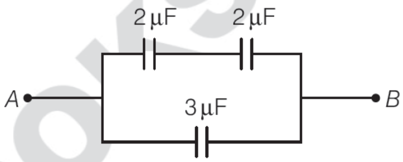
(a) $\dfrac{C}{3}$ (b) $3C$

(c) $\dfrac{C}{4}$ (d) $5C$

27. Three capacitors 3μF, 6μF and 6μF are connected in series to a source of 120 V. The potential difference (in volt) across the 3μF capacitor will be

(a) 40 (b) 30
(c) 40 (d) 60

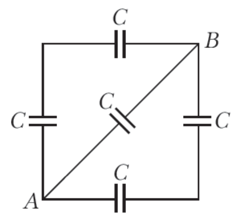
28. Capacitance between points A and B is



(a) 4 μF (b) $\dfrac{12}{7}$ μF

(c) $\dfrac{1}{4}$ μF (d) $\dfrac{7}{12}$ μF

29. In the figure shown, the effective capacitance between the points A and B, if each has capacitance C, is



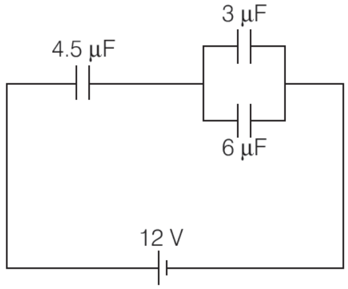
(a) $2C$ (b) $\dfrac{C}{5}$

(c) $5C$ (d) $\dfrac{C}{2}$

30. A parallel plate capacitor is made by stacking n equally spaced plates connected alternately. If the capacitance between any two plates is C, then the resultant capacitance is

(a) C (b) nC
(c) $(n-1)C$ (d) $(n+1)C$

31. In the circuit shown in figure below, the potential difference across the 4.5 μF capacitor is



(a) $\frac{8}{3}$ V (b) 4 V
(c) 6V (d) 8V

32. Across each of two capacitors of capacitance 1μF and a potential difference of 10 V is applied. Then, positive plate of one is connected to the negative plate of the other and negative plate of one is connected to the positive plate of the other. After contact, charge an each plate will be

(a) zero
(b) same but non-zero
(c) different but non-zero
(d) None of the above

33. Work done in placing a charge of 8×10^{-18} C on a condenser of capacity 100 μF is

(a) 16×10^{-32} J (b) 31×10^{-26} J
(c) 4×10^{-10} J (d) 32×10^{-32} J

34. A 5.0 μF capacitor is charged to a potential difference of 800 V and discharged through a conductor. The energy given to the conductor during the discharge is

(a) 1.6×10^2 J (b) 3.2 J
(c) 1.6 J (d) 4.2 J

35. If the charge on each plate of a capacitor of 60 μF is 3×10^{-8} C, then energy stored in the capacitor will be

(a) 2.5×10^{-15} J (b) 1.5×10^{-14} J
(c) 3.5×10^{-13} J (d) 7.5×10^{-12} J

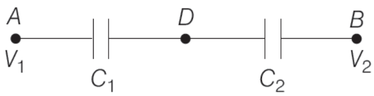
36. The energy required to charge a parallel plate condenser of plate separation d and plate area of cross-section A such that the uniform electric field between the plates E is

(a) $\frac{1}{2}\frac{\varepsilon_0 E^2}{Ad}$ (b) $\frac{\varepsilon_0 E^2}{Ad}$
(c) $\varepsilon_0 E^2 Ad$ (d) $\frac{1}{3}\frac{\varepsilon_0 E^2}{Ad}$

37. The potential energy of a charged parallel plate capacitor is U_0. If a slab of dielectric constant K is inserted between the plates, then new potential energy will be

(a) $\frac{U_0}{K}$ (b) $U_0 K^2$
(c) $\frac{U_0}{K^2}$ (d) U_0^2

38. Two condensers C_1 and C_2 in a circuit are joined as shown in figure. The potential of point A is V_1 and that of B is V_2. The potential of point D will be



(a) $\frac{1}{2}(V_1 + V_2)$ (b) $\frac{C_2V_1 + C_1V_2}{C_1 + C_2}$
(c) $\frac{C_1V_1 + C_2V_2}{C_1 + C_2}$ (d) $\frac{C_2V_1 - C_1V_2}{C_1 + C_2}$

39. Two identical capacitors, have the same capacitance C. One of them is charged to potential V_1 and the other to V_2. Likely charged plates are then connected. Then the decrease in energy of the combined system is

(a) $\frac{1}{4}C(V_1^2 - V_2^2)$ (b) $\frac{1}{4}C(V_1^2 + V_2^2)$
(c) $\frac{1}{4}C(V_1 - V_2)^2$ (d) $\frac{1}{4}C(V_1 + V_2)^2$

40. Two identical capacitors each of capacitance 5 μF are charged to potentials 2 kV and 1 kV, respectively and their negative ends are connected together. When the positive ends are also connected together, the loss of energy of the system is

(a) 160 J (b) zero
(c) 5 J (d) 1.25 J

41. A capacitor is charged by a battery, the battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system

(a) increases by a factor of 4
(b) decreases by a factor of 2
(c) remains the same
(d) increases by a factor of 2

42. The physical quantity having SI unit $NC^{-1}m$ is ……… .

(a) electric potential
(b) electric dipole
(c) electric field
(d) magnetic field

43. A proton released from rest in an electric field, will start moving towards a region of ……… potential in the field,

(a) increasing
(b) decreasing
(c) Both (a) and (b)
(d) constant

44. Equipotential surface due to a point charge is …… .

(a) parallel plane
(b) cylindrical
(c) spherical
(d) perpendicular plane

45. Electrostatic potential energy is stored when a dipole is placed in the electric field. The energy is maximum at ………… .

(a) 180° (b) 0°
(c) 360° (d) 90°

46. A dielectric induces …… in an external electric field which decreases the net electric field.

(a) current (b) dipole moment
(c) magnetic field (d) polarisation

47. Choose the incorrect statement.
Equipotential surfaces

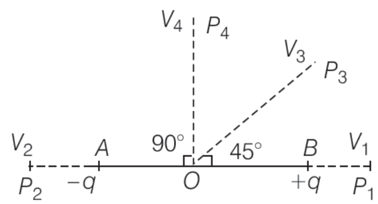
(a) are closer in regions of large electric fields compared to regions of lower electric fields.
(b) will be more crowded near sharp edges of a conductor.
(c) will be more crowded near regions of large charge densities.
(d) will always be equally spaced.

48. The electrostatic potential on the surface of a charged conducting sphere is 100V. Two statements are made in this regard

$\mathbf{S_1}$ at any point inside the sphere, electric intensity is zero.
$\mathbf{S_2}$ at any point inside the sphere, the electrostatic potential is 100V.
Which of the following is a correct statement?

(a) S_1 is true but S_2 is false
(b) Both S_1 and S_2 are false
(c) S_1 is true, S_2 is also true and S_1 is the cause of S_2
(d) S_1 is true, S_2 is also true but the statements are independent

49. Match the Column I (potential) with Column II (value) for electric potential at different points P_1, P_2, P_3 and P_4 as shown in the figure with respect to an electric dipole.



Each points P_1, P_2, P_3 and P_4 are equal distance r from mid-point O of dipole.

	Column I		Column II
A.	V_1	p.	0
B.	V_2	q.	$\dfrac{p}{4\sqrt{2}\pi\varepsilon_0 r^2}$
C.	V_3	r.	$\dfrac{-p}{4\pi\varepsilon_0 r^2}$
D.	V_4	s.	$\dfrac{p}{4\pi\varepsilon_0 r^2}$

Codes

	A	B	C	D
(a)	r	s	q	p
(b)	p	q	r	s
(c)	s	r	q	p
(d)	s	r	p	q

50. A parallel plate capacitor is charged by a battery which is then disconnected. A dielectric slab is then inserted to fill the space between the plates. Match the changes that could occur with Column II.

	Column I		Column II
A.	Charge on the capacitor plates	p.	Decrease by a factor of K
B.	Intensity of electric field	q.	Increase by a factor of K
C.	Energy stored	r.	Remains same
D.	Capacitance	s.	None

Codes

	A	B	C	D
(a)	r	p	s	q
(b)	r	p	p	q
(c)	r	s	p	q
(d)	p	p	q	s

51. Match the Column I (energy of capacitor) with Column II (value) and select the correct answer from the codes given below.

A capacitor C_1 of capacitance C is charged to a potential difference V_0. The terminals of the charged capacitor are then connected to an uncharged capacitor C_2 of capacitance $C/2$.

	Column I		Column II
A.	Final energy of capacitor C_1	p.	$-(1/6)\,CV_0^2$
B.	Final energy of capacitor C_2	q.	$(1/6)\,CV_0^2$
C.	Final energy of the system	r.	$(1/3)\,CV_0^2$
D.	Change in energy on joining the capacitors	s.	$(2/9)\,CV_0^2$
		t.	$(1/9)\,CV_0^2$

Codes

	A	B	C	D		A	B	C	D
(a)	p	q	r	t	(b)	s	t	r	p
(c)	t	s	r	p	(d)	p	q	r	s

Assertion/ Reasoning MCQs

For question numbers 52 to 66, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

52. Assertion Due to two point charges, electrical field and electric potential cannot be zero at same point simultaneously.

Reason Field is a vector quantity and potential a scalar quantity.

53. Assertion An electron moves from a region of lower potential to a region of higher potential.

Reason An electron has a negative charge.

54. Assertion Five charges $+q$ each are placed at five vertices of a regular pentagon. A sixth charge $-Q$ is placed at the centre of pentagon, then net electrostatic force on $-Q$ is zero.

Reason Net electrostatic potential at the centre is zero.

55. Assertion Electric field is always normal to equipotential surfaces and along the direction of decreasing order of potential.

Reason Negative gradient of electric potential is electric field.

56. Assertion No work is done in moving a charge along equatorial line.

Reason The electric potential is everywhere zero on the equatorial line of a dipole.

57. Assertion The expression of potential energy $U = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{12}}$, is unaltered whatever way the charges are brought to the specified locations.

Reason Path-independence of work for electrostatic force.

58. Assertion When two positive point charges move away from each other, then their electrostatic potential energy decreases.

Reason Change in potential energy between two points is equal to the work done by electrostatic forces.

59. Assertion Conductor having equal positive charge and volume, must also have same potential.

Reason Potential depends only on charge and volume of conductor.

60. Assertion In the absence of an external electric field, the dipole moment per unit volume of a polar dielectric is zero.

Reason The dipoles of a polar dielectric are randomly oriented.

61. Assertion Polar molecules do not have permanent dipole moment.

Reason In polar molecules, the centre of positive and negative charges coincides even when there is no external field.

62. Assertion A capacitor can be given only a limited quantity of charge.

Reason Charge stored by a capacitor depends on the shape and size of the plates of capacitor and the surrounding medium.

63. Assertion Capacity of a parallel plate capacitor increases when distance between the plates is increased.

Reason Capacitance of a capacitor is directly proportional to distance between them.

64. Assertion If the distance between parallel plates of a capacitor is halved and dielectric constant is made three times, then the capacitance becomes 6 times.

Reason Capacity of the capacitor depends upon the nature of the material between the plates.

65. Assertion A charged capacitor is disconnected from a battery. Now, if its plate are separated, further the potential energy will fall.

Reason Energy stored in a capacitor is not equal to the work done in charging it.

66. **Assertion** When a capacitor is charged by a battery, half of the energy supplied by the battery is stored in the capacitor and rest half is lost.

Reason If resistance in the circuit is zero, then there will be no loss of energy.

Case Based MCQs

Direction *Answer the questions from 67-71 on the following case.*

Equipotential Surface

In physics, the region in space where every point in it is at the same potential, is called equipotential or isopotential. An equipotential region of a scalar potential in three-dimensional space is often an equipotential surface, but it can also be a three-dimensional region in space. The gradient of the scalar potential is everywhere perpendicular to the equipotential surface, and zero inside a three-dimensional equipotential region. In case of electrical conductors, if a and b are any two points within or at the surface of a given conductor, and given there is no flow of charge being exchanged between the two points, then the potential difference is zero between the two points. Thus, an equipotential would contain both points a and b as they have the same potential.

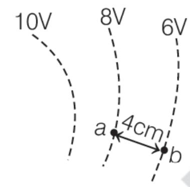
67. For a uniform electric field E, along the X-axis, the equipotential surfaces are plane

(a) perpendicular to Z-axis
(b) parallel to the yz-plane
(c) perpendicular to yz-plane
(d) perpendicular to Y-axis

68. Equipotentials at a least distance from a collection of charges whose total sum is not zero are approximately

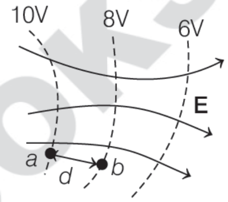
(a) spheres (b) planes
(c) paraboloids (d) ellipsoids

69. Three equipotential surface are shown in the figure below

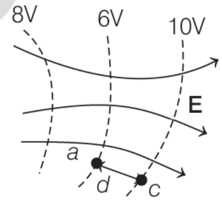


Which of the following option correctly represents the corresponding field lines?

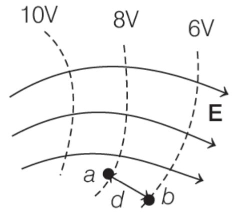
(a)



(b)



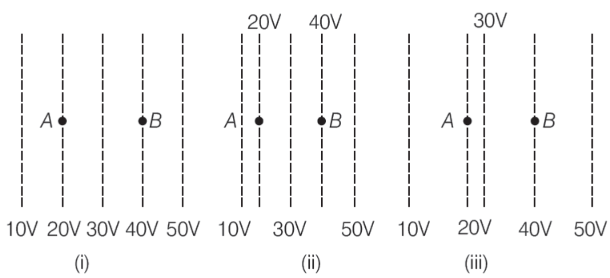
(c)



(d) None of the above

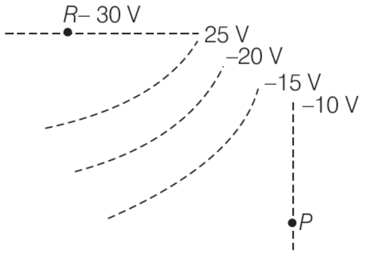
70. Figure shows some equipotential lines distributed in space. A charged object is moved from point A to point B.

(NCERT Exemplar)



(a) The work done in Fig. (i) is the greatest
(b) The work done in Fig. (ii) is least
(c) The work done is the same in Fig. (i), Fig.(ii) and Fig. (iii)
(d) The work done in Fig. (iii) is greater than Fig. (ii)

71. The figure given below shows various equipotential surfaces.



What is the direction of electric field **E** at P and R ?

(a) At P, **E** is to the left and at R, **E** is upward.
(b) At P, **E** is to the right and at R, **E** is downward.
(c) At P, **E** is to downward and at R, **E** is to the left.
(d) At P, **E** is to upward and at R, **E** is to the right.

Direction *Answer the questions from 72-76 on the following case.*

Electrostatic Potential Energy

Electrostatic potential energy of a system of point charges is defined as the total amount of work done in bringing the different charges to their respective positions from infinitely large mutual separations.

By definition, work done in carrying charge from ∞ to any point is

$$W = \text{Potential} \times \text{Charge}$$

This work is stored in the system of two point charges in the form of electrostatic potential energy U of the system.

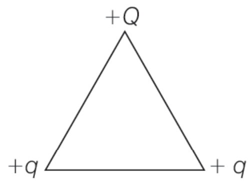
72. Work done in moving a charge from one point to other inside a uniformly charged conducting sphere is

(a) always zero (b) non-zero
(c) may be zero (d) None of these

73. A positively charged particle is released from rest in an uniform electric field. The electric potential energy of the charge

(a) remains a constant because the electric field is uniform
(b) increases because the charge moves along the electric field
(c) decreases because the charge moves along the electric field
(d) decreases because the charge moves opposite to the electric field

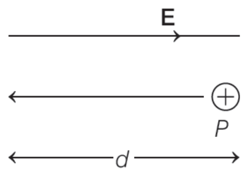
74. Three charges are placed at the vertex of an equilateral triangle of side l as shown in figure. For what value of Q, the electrostatic potential energy of the system is zero?



(a) $-q$ (b) $q/2$
(c) $-2q$ (d) $-q/2$

75. In the figure, proton moves a distance d in a uniform electric field E as shown in the figure.

The work done on the proton by electric field is



(a) negative
(b) positive
(c) zero
(d) None of the above

76. Two similar positive point charges each of 1 μC have been kept in air at 1m distance from each other. What will be the potential energy?

(a) 1 J (b) 1 eV (c) 9×10^{-3} J (d) zero

Direction *Answer the questions from 77-81 on the following case.*

Capacitor

A device that stores electrical energy in an electric field is known as to be capacitor. It is a passive electronic component with two terminals. It basically consists of two conductors separated by a non-conductive region. This non-conductive region can either be a vacuum or an electrical insulator material known as a dielectric from Coulomb's law a charge on one conductor will exert a force on the charge carriers within the other conductor, attracting opposite polarity charge and repelling like polarity charges, thus an opposite polarity charge will be induced on the surface of the other conductor. The conductors thus hold equal and opposite charges on their facing surfaces, and the dielectric develops an electric field.

An ideal capacitor is characterised by a constant capacitance C. In farads in the SI system of units, defined as the ratio of the positive or negative charge Q on each conductor to the voltage V between them. Parallel plate capacitor is the most commonly used capacitor.

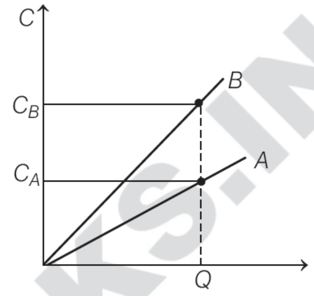
77. Consider a parallel plate air capacitor, its capacitance does not depends on

(a) thickness of conducting plates
(b) charge on the conducting plates
(c) area of the conducting plates
(d) distance of separation between the conducting plates

78. When a dielectric is placed in an electric field, the electric field inside the dielectric

(a) increases
(b) decreases
(c) constant
(d) zero

79. The graph shows the variation of capacitances the plates of two capacitors A and B *versus* increase of charge Q stored in them. Which of the capacitors has higher potential?



(a) Capacitor A
(b) Capacitor B
(c) Both have same capacitance
(d) None of the above

80. A parallel plate capacitor with plates of area 1 m^2 each, are at a separation of 0.1 m. If the electric field between the plates is 100 N/C, the magnitude of charge on each plate is

$$\left(\text{Take, } \varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N\text{-}m^2}\right)$$

(a) 9.85×10^{-10} C
(b) 8.85×10^{-10} C
(c) 7.85×10^{-10} C
(d) 6.85×10^{-10} C

81. The capacitance of capacitor will decrease if we introduce a slab of

(a) copper
(b) aluminium
(c) zinc
(d) None of the above

Direction *Answer the questions from 82-86 on the following case.*

Dielectrics

Dielectrics are insulating (non-conducting) materials that can produce electric effect without conduction. Movement of free charges is not possible in a dielectric, so they behave differently.

When a dielectric material is kept in an electric field, then the external field induces dipole moment. Due to which, net charges on the surface of the dielectric appears.

82. When a dielectric material is kept in an external field, then the induced field will be

(a) less (b) more
(c) Both (a) and (b) (d) constant

83. In the absence of electric field, the net dipole moment of a polar dielectric is

(a) zero
(b) infinite
(c) positive
(d) negative

84. Molecules that has no permanent dipole moments are

(a) polar dielectrics
(b) non-polar dielectrics
(c) Both (a) and (b)
(d) None of the above

85. The SI unit of dielectric strength is

(a) Vm^{-1} (b) Vm
(c) mV^{-1} (d) m^2V

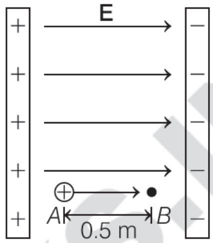
86. Which of the following is/are the examples of non-polar molecules?

(a) Oxygen (b) Hydrogen
(c) Nitrogen (d) All of these

Direction *Answer the questions from 87-91 on the following case.*

Proton in an Electric Field

Potential difference (ΔV) between two points A and B separated by a distance x, in a uniform electric field $\mathbf{E}$ is given by $\Delta V = -Ex$, where x is measured parallel to the field lines. If a charge q_0 moves from A to B, 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 8.0×10^4 Vm^{-1} directed along the positive X-axis. The proton undergoes a displacement of 0.50 m in the direction of E.



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

87. As the proton moves from B to A, 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

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

(a) 4.0×10^4 V (b) -4.0×10^4 V
(c) 6.4×10^{-19} V (d) -6.4×10^{-19} V

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

(a) -6.4×10^{-19} J (b) 6.4×10^{-19} J
(c) -6.4×10^{-15} J (d) 6.4×10^{-15} J

90. The velocity (v_B) of the proton after it has moved 0.50 m starting from rest is

(a) 1.6×10^8 ms^{-1} (b) 2.77×10^6 ms^{-1}
(c) 2.77×10^4 ms^{-1} (d) 1.6×10^6 ms^{-1}

91. If in place of charged plates, two similar point charges of 1 μC have kept in air at 1m distance from each other, then potential energy is

(a) 1 J (b) 1 eV
(c) 9×10^{-3}J (d) zero

ANSWERS

Multiple Choice Questions

1. (a)	2. (b)	3. (d)	4. (c)	5. (b)	6. (c)	7. (d)	8. (b)	9. (c)	10. (b)
11. (c)	12. (b)	13. (a)	14. (c)	15. (b)	16. (b)	17. (d)	18. (a)	19. (a)	20. (a)
21. (a)	22. (a)	23. (b)	24. (c)	25. (c)	26. (a)	27. (d)	28. (a)	29. (a)	30. (c)
31. (d)	32. (c)	33. (d)	34. (c)	35. (d)	36. (c)	37. (a)	38. (c)	39. (c)	40. (d)
41. (d)	42. (a)	43. (b)	44. (c)	45. (a)	46 (b)	47. (d)	48. (c)	49 (c)	50. (b)
51. (b)									

Assertion/Reasoning MCQs

52. (b)	53. (a)	54. (c)	55. (a)	56. (c)	57. (a)	58. (b)	59. (d)	60. (a)	61. (c)
62. (a)	63. (d)	64. (b)	65. (d)	66. (c)					

Case Based MCQs

67. (b)	68. (b)	69. (c)	70. (c)	71. (a)	72. (a)	73. (c)	74. (d)	75. (a)	76. (c)
77. (b)	78. (b)	79. (a)	80. (b)	81. (d)	82. (a)	83. (a)	84. (b)	85. (a)	86. (d)
87. (b)	88. (b)	89. (c)	90. (b)	91. (c)					

SOLUTIONS

1. From the definition of potential,

$$V = \frac{\text{Work done}}{\text{Charge}} = \frac{W}{q}$$

$\therefore$ Unit of potential $= \dfrac{\text{Joule (J)}}{\text{Coulomb (C)}}$

2. Potential at a point in a field is defined as the amount of work done in bringing a unit positive charge (q) from to that point along any arbitrary path,

$$V = \frac{W}{q}$$

$\therefore$ Work done, $W = qV$

3. Given, $W_{AB} = 100$ J, $q_0 = 4$ C

$$V_A = -10 \text{ V}$$

and $V_B = V$

Since, $V_B - V_A = \dfrac{W_{AB}}{q_0}$, by external force

$$V - (-10\text{V}) = \frac{100 \text{ J}}{4 \text{ C}} = 25 \text{ V}$$

or $V = 25 \text{ V} - 10 \text{ V} = 15 \text{ V}$

4. Given, $q = 3\text{nC} = 3 \times 10^{-9}$ C

$$r = 9 \text{ cm} = 9 \times 10^{-2} \text{ m}$$

We know that, potential due to point charge is given by

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r} = \frac{9 \times 10^9 \times 3 \times 10^{-9}}{9 \times 10^{-2}}$$

$$= 3 \times 10^2$$

$\Rightarrow$ $V = 300$ V

5. The potential at the centre of metallic hollow spherical surface is 10 V, because potential at any point inside a hollow metallic sphere is constant. Thus, potential at the centre is equal to the potential at surface of the sphere.

6. Volume of eight drops = Volume of a big drop

$$\therefore \quad \left(\frac{4}{3}\pi r^3\right) \times 8 = \frac{4}{3}\pi R^3$$

$$\Rightarrow \quad 2r = R \qquad \ldots\text{(i)}$$

According to charge conservation,

$$8q = Q \qquad \ldots\text{(ii)}$$

Potential of one small drop, $V' = \dfrac{q}{4\pi\varepsilon_0 r}$

Similarly, potential of big drop,

$$V = \frac{Q}{4\pi\varepsilon_0 R}$$

Now, $\frac{V'}{V} = \frac{q}{Q} \times \frac{R}{r}$

$\Rightarrow \quad \frac{V'}{20} = \frac{q}{8q} \times \frac{2r}{r}$ [from Eqs. (i) and (ii)]

$\therefore \quad V' = 5\text{ V}$

So, the potential of each single drop was 5V.

7. The potential of electric dipole at a distance r from the centre of dipole is

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p\cos\theta}{r^2}$$

$$\Rightarrow \quad V \propto \frac{1}{r^2}$$

where, p is dipole moment.

8. The potential due to an electric dipole is

$$V = \frac{1}{4\pi\varepsilon_0} \frac{\mathbf{p}\cdot\mathbf{r}}{r^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{pr\cos\theta}{r^2}$$

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{pr\cos\left(\frac{\pi}{2}\right)}{r^2} \qquad \left[\because \theta = \frac{\pi}{2}\right]$$

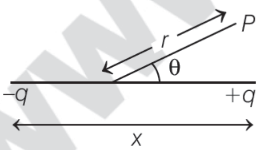
$$= 0$$

Thus, the potential in the equatorial plane of a dipole of dipole moment p is zero.

9. Electric potential at point P is given is

$$V_q = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2qx\cos\theta}{r^2}$$

where, r is the distance of observation point from the centre of dipole.



Hence, the value of potential at very far point will depend upon $q \cdot x$.

10. The relation between electric field intensity E and electric potential V is given as

$$E = \frac{-dV}{dr}$$

So, for constant V, we have $\frac{dV}{dr} = 0$

$$\Rightarrow \quad E = 0$$

Therefore, electric field intensity will be zero.

11. The positively charged particle experiences electrostatic force along the direction of electric field, i.e. from high electrostatic potential to low electrostatic potential. Thus, the work is done by the electric field on the positive charge, hence electrostatic potential energy of the positive charge decreases.

12. The electric field is maximum at B, because electric field is directed along decreasing potential $V_B > V_C > V_A$.

13. In this problem, the collection of charges, whose total sum is not zero, with regard to great distance can be considered as a point charge. The equipotential due to point charges are spherical in shape as electric potential due to point charge q is given by

$$V = k_e \cdot \frac{q}{r}$$

This suggest that electric potentials due to point charge is same for all equidistant points. The locus of these equidistant points, which are at same potential, form spherical surface.

14. Electrostatic potential energy,

$$U = \frac{1}{4\pi\varepsilon_0} \frac{q_1q_2}{\lambda}$$

$$\therefore \quad U = \frac{9\times10^9 \times (1.6\times10^{-19}) \times (-1.6\times10^{-19})}{10^{-10}}\text{ J}$$

$$= -9\times10^9 \times 1.6\times10^{-9}$$

$$= -14.4\text{ eV}$$

15. Conductors are materials through which electric charge can flow easily. Inside a conductor, electrostatic field is zero. So, the electric potential of earth is zero and behaves as a good conductor.

16. In the presence of external electric field, find the potentials at position of q_1 and q_2.

Total electrostatic energy of system

$$= q_1V_1 + q_2V_2 + \frac{kq_1q_2}{r_{12}} \qquad \ldots\text{(i)}$$

and $r_{12} = (r_1 - r_2)$

$= (9 + 9)$

$= 18\text{ cm} = 0.18\text{ m}$

Substituting the given values in Eq. (i), we get

$$= A\left(\frac{-2\times10^{-6}}{0.09}\right) + A\left(\frac{7\times10^{-6}}{0.09}\right) + \left(\frac{-9\times10^{9}\times7\times2\times10^{-12}}{0.18}\right)$$

$$= \frac{9\times10^{5}\,(5\times10^{-6})}{0.09} - 0.7\text{ J}$$

$$= 50\text{ J} - 0.7 = 49.3\text{ J}$$

17. Given, $\mathbf{E} = 1000$ V/m, $\theta = 45°$

and $\mathbf{p} = 10^{-27}$ C-m

We know that, electric potential energy stored in an electric dipole kept in uniform electric field is given by the relation,

$$U = -\mathbf{p}\cdot\mathbf{E} = -pE\cos\theta$$

$$= -10^{-27}\times1000\times\cos45°$$

$$\Rightarrow \quad U \approx -7\times10^{-25}\text{ J}$$

18. There must be charges on the surface or inside it, because a conductor cannot have a non-zero potential without the presence of net charge. If there are no charge externally, then the conductor itself must have charges inside or on the surface of conductor.

19. From the given graphs, the voltages V_A and V_B of capacitors A and B corresponding to charge Q on each of the capacitors are

$$V_A = \frac{Q}{C_A} \quad\text{and}\quad V_B = \frac{Q}{C_B}$$

or $$\frac{V_B}{V_A} = \frac{Q/C_B}{Q/C_A} = \frac{C_A}{C_B}$$

Since, $V_B > V_A \Rightarrow C_A > C_B$, i.e. the capacitor A has the higher capacitance than B.

20. Potential difference between the plates of the capacitor $= +30 - (-10) = 40$ V

Electric field between plates of capacitor

$$= \frac{\text{Potential difference}}{\text{Separation between the plates}}$$

$$= \frac{40}{2} = 20\text{ V/m}$$

21. Force, $F_e = qE = q\left(\frac{V}{d}\right)$

$$= (4\times10^{-6})\left(\frac{2000}{2\times10^{-3}}\right) = 4\text{ N}$$

22. Capacitance, $C = \frac{\varepsilon_0 A}{d}$

$$\varepsilon_0 = 8.85\times10^{-12}\text{ C}^2\text{ m}^{-2}\text{ N}^{-1}$$

$$r = 8\text{ cm} = 0.08\text{ m}$$

$$A = \pi r^2 = (3.14\times0.08\times0.08)\text{ m}^2$$

$$d = 1\text{ mm} = 1\times10^{-3}\text{ m}$$

Charge, $q = CV \Rightarrow \frac{\varepsilon_0 A}{d}\times V$

$$\Rightarrow \frac{8.85\times10^{-12}\times3.14\times(0.08)^2}{1\times10^{-3}}\times100$$

$$q = 1.78\times10^{-8}\text{ C}$$

23. In free space, electric field between capacitor,

$$E_0 = \frac{q}{A\varepsilon_0} \quad\ldots\text{(i)}$$

When plates of capacitor dipped in oil tank, then the electric field between plates of capacitor,

$$E_K = \frac{q}{A\varepsilon} \quad\ldots\text{(ii)}$$

From Eqs. (i) and (ii), we get

$$E_K = \frac{E_0}{K} \quad (\because E = K\,\varepsilon_0)$$

Hence, electric field between the plates is decreased.

24. $\because$ $$C_0 = \frac{\varepsilon_0 A}{d} = 18 \quad\ldots\text{(i)}$$

and $$C = \frac{K\varepsilon_0 A}{3d} = 72 \quad\ldots\text{(ii)}$$

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

$$\frac{K}{3} = \frac{72}{18} = 4$$

$\therefore$ Dielectric constant, $K = 12$

25. The capacitance of parallel plate capacitor filled with dielectric block has thickness d_1 and dielectric constant K_1 is given by

$$C_1 = \frac{K_1\,\varepsilon_0 A}{d_1}$$

Similarly, capacitance of parallel plate capacitor filled with dielectric block has thickness d_2 and dielectric constant K_2 is given by

$$C_2 = \frac{K_2 \varepsilon_0 A}{d_2}$$

The equivalent capacitance can be given by

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

or $$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{\frac{K_1 \varepsilon_0 A}{d_1} \frac{K_2 \varepsilon_0 A}{d_2}}{\frac{K_1 \varepsilon_0 A}{d_1} + \frac{K_2 \varepsilon_0 A}{d_2}}$$

$$= \frac{K_1 K_2 \varepsilon_0 A}{K_1 d_2 + K_2 d_1} \quad ...(i)$$

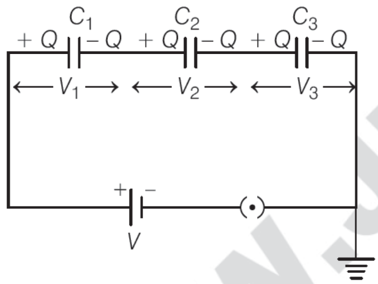
But the equivalent capacitance is given by

$$C = \frac{K \varepsilon_0 A}{d_1 + d_2}$$

On comparing, we have

$$K = \frac{K_1 K_2 (d_1 + d_2)}{K_1 d_2 + K_2 d_1}$$

26. The equivalent capacitance C_s is given by



$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \quad [\because C_1 = C_2 = C_3 = C]$$

$$C_s = \frac{C}{3}$$

27. The combination of three capacitors in series,

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$= \frac{1}{3} + \frac{1}{6} + \frac{1}{6}$$

$$\Rightarrow \quad C = \frac{6}{4} = 1.5 \mu F$$

The charge of this circuit,

$$q = CV = 1.5 \times 120 = 180 \ \mu C$$

The potential difference across $3 \mu F$,

$$q = CV$$

$$\Rightarrow \quad V = \frac{q}{C} = \frac{180}{3} = 60 \text{ V}$$

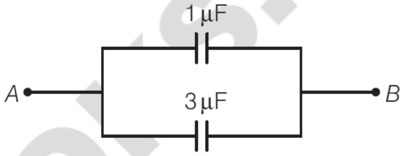
28. Two capacitors of $2 \ \mu F$ capacitance are connected in series order and their equivalent capacitance,

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

$$= \frac{1}{2} + \frac{1}{2} = \frac{2}{2} = 1$$

$$\therefore \quad C_s = 1$$

Now, $C_s = 1 \ \mu F$ and $3 \ \mu F$ capacitors are connected in parallel order.

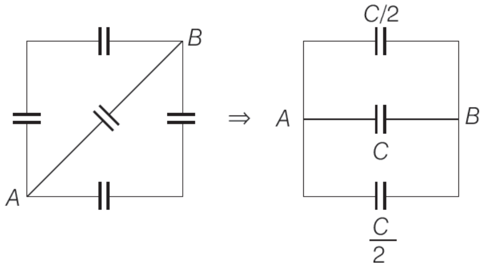


Equivalent capacitance between point is A and B,

$$C_{AB} = C_s + C_3$$

$$= 1 + 3 = 4 \ \mu F$$

29. The given circuit can be simplified as follows



Equivalent capacitance between A and B,

$$C_{AB} = \frac{C}{2} + \frac{C}{2} + C = 2C$$

30. The given arrangement becomes an arrangement of $(n-1)$ capacitors connected in parallel, so $C_R = (n-1)C$.

31. In the given circuit, net capacitance of $3 \ \mu F$ and $6 \ \mu F$ capacitors being connected in parallel,

$$C' = 3 \mu F + 6 \mu F = 9 \mu F$$

Now, $4.5 \ \mu F$ and $9 \ \mu F$ capacitors are in series, so the total capacity of capacitor,

$$C = \frac{9 \times 4.5}{9 + 4.5} = \frac{9 \times 4.5}{13.5} = 3 \ \mu F$$

Charge, $q = CV = 3 \times 12 = 36 \ \mu F$

(given, $V = 12$ V)

$\therefore$ Potential difference across 4.5 μF,

$$V' = \frac{q}{4.5} = \frac{36}{4.5} = 8 \text{ V}$$

32. Let C_1 and C_2 be two parallel plate capacitors. The potential difference between plates is 10V. The combination of the two capacitors according to question is given as follows

The negative plate of C_1 is attached to positive plate of C_2. The transfer of charges takes places and both the plates are neutralised. But, the negative plate of C_2 and positive plate of C_1 still has some finite amount of charge.

33. Here, $q = 8 \times 10^{-18}$ C

and $\quad C = 100\,\mu\text{F} = 10^{-4}$ F

$$\therefore \qquad V = \frac{q}{C} = \frac{8 \times 10^{-18}}{10^{-4}} = 8 \times 10^{-14} \text{ V}$$

$\therefore$ Work done, $W = \frac{1}{2} qV$

$$= \frac{1}{2} \times 8 \times 10^{-18} \times 8 \times 10^{-14}$$

$$= 32 \times 10^{-32} \text{ J}$$

34. Energy given to conductor $= \frac{1}{2} CV^2$

$$= \frac{1}{2} \times 5 \times 10^{-6} \times (800)^2 = 1.6 \text{ J}$$

35. Energy stored in capacitor, $U = \frac{1}{2} \frac{q^2}{C}$

Here, $q = 3 \times 10^{-8}$ C

and $C = 60\,\mu\text{F} = 60 \times 10^{-6}$ F

$$\therefore \qquad U = \frac{1}{2} \times \frac{(3 \times 10^{-8})^2}{60 \times 10^{-6}} = 7.5 \times 10^{-12} \text{ J}$$

36. Energy of charged capacitor $= \frac{1}{2} CV^2$

Energy given by cell $= CV^2 = \frac{A\varepsilon_0}{d} \times (Ed)^2$

As, $V = Ed = A\varepsilon_0 E^2 d$

37. Potential energy of charged parallel plate capacitor, $U_0 = \frac{Q^2}{2C}$

When a slab of dielectric K is inserted, then $C' = CK$.

The new potential energy,

$$U = \frac{Q^2}{2C'} = \frac{Q^2}{2CK} = \frac{U_0}{K}$$

38. As capacitors C_1 and C_2 are in series, then there should be equal charge on them. i.e.

Charge on C_1 = Charge on C_2

$\therefore C_1(V_A - V_D) = C_2(V_D - V_B)$

or $\; C_1(V_1 - V_D) = C_2(V_D - V_2)$

or $\; C_1V_1 - C_1V_D = C_2V_D - C_2V_2$

or $\; V_D(C_1 + C_2) = C_1V_1 + C_2V_2$

The potential difference of point D,

$$V_D = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

39. ΔU = decrease in potential energy

$$= U_i - U_f$$

$$= \frac{1}{2} C(V_1^2 + V_2^2) - \frac{1}{2}(2C)\left(\frac{V_1 + V_2}{2}\right)^2$$

$$= \frac{1}{4} C(V_1 - V_2)^2$$

40. Loss of energy, $U = \frac{1}{2} \frac{C_1C_2}{(C_1 + C_2)} (V_1 - V_2)^2$

$$= \frac{1}{2}\left[\frac{5 \times 10^{-6} \times 5 \times 10^{-6} (2000 - 1000)^2}{(5 + 5) \times 10^{-6}}\right]$$

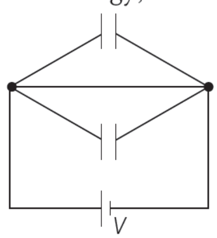
$$= \frac{5 \times 5}{2 \times 10} = 1.25 \text{ J}$$

41. Energy stored in a system of capacitors

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

Also, potential drop remains same in parallel combination across both the capacitors.

Initially stored energy,



$$U_1 = \frac{1}{2} CV^2$$

Finally, potential drop across each capacitor will be V.

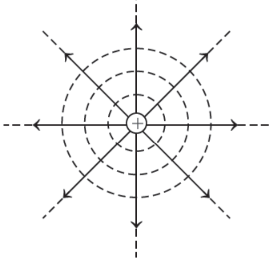
So, finally stored energy,

$$U_2 = \frac{1}{2}CV^2 + \frac{1}{2}CV^2 = \frac{1}{2}(2C)V^2$$
$$= 2\left(\frac{1}{2}CV^2\right) = 2U_1$$

42. The physical quantity having SI unit $NC^{-1}m$ is electric potential.

43. As, electric field lines starts from higher potential and ends at lower potential, so when a proton is released from rest in the field, then it moves towards the region of decreasing potential in the field.

44. The equipotential surfaces produced by a point charge or a spherically symmetrical charge distribution is as shown below



It is represented by a family of concentric spheres.

45. Potential energy of dipole, $U = -pE\cos\theta$
Hence, potential energy is minimum at $\theta = 0°$ and maximum at $\theta = 180°$.

46. When a dielectric is placed in an external electric field, a net dipole moment is induced in the dielectric. It lowers down the net electric field.

47. The statement given in option (d) is incorrect and it can be corrected as,

Because the electric field intensity is large near sharp edges of charged conductor and near regions of large charge densities.

Therefore, equipotential surfaces are not always equally spaced.

Rest statements are correct.

48. In this problem, the electric field intensity E and electric potential V are related as

$$E = -\frac{dV}{dr}$$

Electric field intensity $E = 0$ suggest that

$$\frac{dV}{dr} = 0$$

This imply that, V = constant.

Thus, $E = 0$ inside the charged conducting sphere. So, the same electrostatic potential 100V at any point inside the sphere.

49. A. Electric potential at any point due to electric dipole is given as $V = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$

At point P_1, $\theta = 0°$

$$\Rightarrow \quad V_1 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p\cos 0°}{r^2} = \frac{p}{4\pi\varepsilon_0 r^2}$$

B. At point P_2, $\theta = 180°$

$$\Rightarrow \quad V_2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p\cos 180°}{r^2} = \frac{-p}{4\pi\varepsilon_0 r^2}$$

C. At point P_3, $\theta = 45°$

$$\Rightarrow \quad V_3 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p\cos 45°}{r^2} = \frac{p}{4\sqrt{2}\pi\varepsilon_0 r^2}$$

D. At point P_4, $\theta = 90°$

$$\Rightarrow \quad V_4 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{p\cos 90°}{r^2} = 0$$

Hence, A → s, B → r, C → q and D → p.

50. A dielectric slab is then inserted to fill the space between the plates and battery is removed, then

Quantity	Battery is removed
Capacity	$C' = KC$
Charge	$Q' = Q$
Potential	$V' = V/K$
Intensity	$E' = E/K$
Energy	$U' = U/K$

Hence, A → r, B → p, C → p and D → q.

51. A. As, $\frac{Q_1}{C_1} = \frac{Q_2}{C_2}$, $Q_2 = \left(\frac{C_2}{C_1}\right)Q_1$

$$= \frac{(C/2)}{C}Q_1 = \frac{Q_1}{2}$$

Further as,

$$Q = Q_1 + Q_2 = Q_1 + \frac{Q_1}{2} = \frac{3}{2}Q_1$$

$$Q_1 = \frac{2}{3}Q \text{ and } Q_2 = \frac{1}{3}Q$$

Final energy of capacitor C_1,

$$U_1 = \frac{Q_1^2}{2C_1} = \frac{\left(\frac{2}{3}Q\right)^2}{2C}$$

$$= \frac{2}{9}CV_0^2$$

B. Final energy of capacitor C_2,

$$U_2 = \frac{Q_2^2}{2C_2} = \frac{\left(\frac{1}{3}Q\right)^2}{2(C/2)} = \frac{1}{9}\left(\frac{Q^2}{C}\right) = \frac{1}{9}CV_0^2$$

C. Final energy of system,

$$U_{\text{final}} = U_1 + U_2 = \frac{1}{3}CV_0^2$$

D. Inital energy of system,

$$U_{\text{initial}} = \frac{Q^2}{2C} = \frac{(CV_0)^2}{2C} = \frac{1}{2}CV_0^2$$

$\therefore$ Change in energy,

$$\Delta U = U_{\text{final}} - U_{\text{initial}} = -\frac{1}{6}CV_0^2$$

Hence, A $\rightarrow$ s, B $\rightarrow$ t, C $\rightarrow$ r and D $\rightarrow$ p.

52. If electric field at a point is zero due to two point charges, then potential cannot be zero.

Electric field is a vector quantity E whereas potential is a scalar quantity. Therefore, both A and R are true but R is not the correct explanation of A.

53. As electric field is set up from higher potential to lower potential because it is in the direction in which the potential decreases steeply.

So, if an electron having negative charge is placed in electric field, then it will move opposite to the direction of electric field,

i.e. from lower potential to higher potential.

Therefore, both A and R are true and R is the correct explanation of A.

54. Five charges of equal magnitude are acting on $-Q$. When they are added as per polygon law, their vector sum will become zero.

Therefore, A is true, but R is false.

55. The equipotential surfaces are the planes draw perpendicular to the direction of electric field, that have same potential over its surface.

So, electric field is always normal to equipotential surfaces.

The electric field and electric potential are related as

$$E = -\frac{dV}{dr}$$

i.e. Negative gradient of electric potential is electric field.

The negative sign shows that, the potential decreases in the direction of electric field or electric field is along the direction of decreasing order of potential.

Therefore, both A and R are true and R is the correct explanation of A.

56. Work done, $W = q = (V_1 - V_2)$

At the equitorial line, $V_1 = V_2$

$\therefore$ Resultant electric potential at the equatorial potential,

$$(V_1 - V_2) = 0$$

$$\therefore \qquad W = 0$$

Therefore, A is true but R is false.

57. The potential energy, $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$ is unaltered whatever way the charges are brought to the specified locations, because of path-independence of work for electrostatic force.

Therefore, both A and R are true and R is the correct explanation of A.

58. Potential energy of a system of two charges,

$$U = K\frac{q_1 q_2}{r}$$

$\therefore$ When two positive point charges move away from other, then their potential energy decreases and work done by force can always be expressed in terms of change in potential energy, when the particle moves from a point.

Therefore, both A and R are true but R is not the correct explanation of A.

59. Electric potential of a charge conductor depends not only on the amount of charge and volume but also on the shape of the conductor. Hence, if their shapes are different, they may have different electric potential.

Therefore, A is false and R is also false.

60. Polar dielectric molecules are the one in which centres of positive and negative charges are separated even when there is no external field. It means that, they have permanent dipoles.

So, in the absence of any external electric field, the permanent dipoles are oriented randomly due to thermal agition. So, the total dipole moment is zero.

Therefore, both A and R are true and R is the correct explanation of A.

61. The molecules of a substance may be polar or non-polar. In a non-polar molecule, the centre of positive and negative charges coincides.

On the other hand, a polar molecule is one in which the centres of positive and negative charges are separated, even when there is no external field.

So, polar molecules have a permanent dipole moment.

Therefore, A is true but R is false.

62. The maximum amount of charge a capacitor can have depends on the shape and size of capacitor and also on the surrounding medium.

Thus, a capacitor can be given only a limited quantity of charge.

Therefore, both A and R are true and R is the correct explanation of A.

63. Capacitance of a capacitor is inversely proportional to distance between the plates.

So, capacity of a parallel plate capacitor increases when distance between the plates is decreased.

Therefore, A is false and R is also false.

64. $C = \frac{\varepsilon_0 kA}{d} \Rightarrow C \propto \frac{k}{d}$

$$\therefore \quad \frac{C_1}{C_2} = \frac{k_1}{d_1} \times \frac{d_1}{k_2} = \frac{k}{d} \times \frac{d/2}{3k} = \frac{1}{6}$$

$$C_2 = 6C_1$$

Again for capacity of a capacitor,

$$C = \frac{k\varepsilon_0 A}{d}$$

So, capacity of a capacitor depends upon the medium between two plates of capacitor.

Therefore, both A and R are true but R is not the correct explanation of A.

65. Battery is disconnected from the capacitor, so Q = constant.

$$\text{Energy} = \frac{Q^2}{2C} = \frac{Q^2 d}{2\varepsilon_0 A}$$

Energy $\propto d$

Therefore, A is false and R is also false.

66. Energy supplied by battery

$$= qV = (CV)V$$
$$= CV^2$$

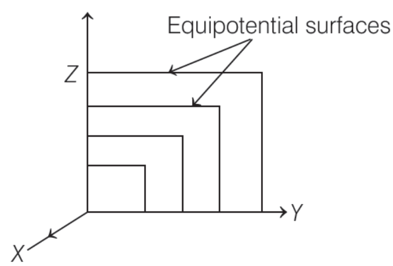
$$\text{Energy stored} = \frac{1}{2}CV^2$$

$$\therefore \text{ Energy lost} = CV^2 - \frac{1}{2}CV^2$$
$$= \frac{1}{2}CV^2$$

Hence, half energy is lost.

Therefore, A is true but R is false.

67. For an electric field in X-axis equipotential surfaces are plane parallel to the YZ-plane.



68. Equipotential surfaces at a least distance from a collection of charges whose total sum is not equal to zero are planer.

69. Equipotential surfaces due to electric field are perpendicular planes to the electric field lines.

Hence, option (c) correctly represents the electrical field lines for the given equipotential surface.

70. The work done by a electrostatic force is given by $W_{12} = q(V_2 - V_1)$. Here, initial and final potentials are same in all three cases and same charge is moved, so work done is same in all three cases.

71. Electric field lines are perpendicular to the equipotential surfaces and point in the direction of decreasing potential. At P, electric field **E** is to the left and at R, electric field **E** is upward.

72. Since, $E = 0$ inside the conductor and has no tangential component on the surface, no work is done in moving a small test charge within the conductor and on its surface.

73. The positively charged particle experiences an electrostatic force along the direction of electric field, i.e. from high electrostatic potential to low electrostatic potential. Thus, the work is done by the electric field on the positive charge, hence electrostatic potential energy of the positive charge decreases.

74. Potential energy of the system,

$$U = \frac{KQq}{l} + \frac{Kq^2}{l} + \frac{KqQ}{l} = 0$$

$$\Rightarrow \quad \frac{Kq}{l} \times [(Q + q + Q)] = 0$$

$$\Rightarrow \quad Q = -q/2$$

75. Since, the proton is moving against the direction of electric field, so work is done on the proton against electric field. It implies that electric field does negative work on the proton. Again, proton is moving in electric field from low potential region to high potential region hence, its potential energy increases.

76. Electric potential energy of the system,

$$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r}$$

Here, $q_1 = q_2 = 1\,\mu\text{C} = 1 \times 10^{-6}$ C,

$$r = 1 \text{ m and } \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N-m}^2/\text{C}^2$$

$$\therefore \quad U = \frac{9 \times 10^9 \times 1 \times 10^{-6} \times 1 \times 10^{-6}}{1}$$

$$= 9 \times 10^{-3} \text{ J}$$

77. As we know, $C = \dfrac{\varepsilon_0 A}{d}$

Hence, capacitance of a parallel plate capacitor depends on the thickness of the plate, area of the conducting plates and distance of separation between the conducting plates.

78. The dielectric material get polarised when it is placed in an electric field. The field produced due to polarisation of the material minimize the effect of external field. Hence, the electrical field inside a dielectric decreases when it is placed in an external field.

79. As we know, $C = \dfrac{Q}{V}$

Capacitor having less potential difference will have more capacitance for a constant value $\left(C \propto \dfrac{1}{V}\right)$ of charge.

Thus, capacitor A has higher capacitance.

80. Given, $d = 0.1$ m, $A = 1$ m^2

$$C = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 1}{0.1} = 8.85 \times 10^{-12} \times 10$$

Also, $\quad C = \dfrac{Q}{V}$

$$\Rightarrow \quad VC = Q \qquad \left(\because E = \frac{V}{d} \Rightarrow V = E \times d\right)$$

$$\therefore \quad Q = C \times E \times d$$

$$Q = 8.85 \times 10^{-12} \times 10 \times 100 \times 0.1$$

$$Q = 8.85 \times 10^{-10} \text{ C}$$

81. All conductive materials have infinite electrical permittivity.

Hence, introducing a conductive metal in a capacitor will increases the electric field inside it. Therefore, option (d) is correct.

82. In external field, when a dielectric slab is kept near it, the magnitude of induced field is less than that of the external field.

83. A polar dielectric is one which is having a net dipole moment zero in the absence of electric field due to the random orientation of polar molecules.

84. In a non-polar molecule, the centres of positive and negative charges coincide. The molecules thus has no permanent dipole moment. e.g. Oxygen (O_2) and Hydrogen (H_2) molecules.

85. The maximum electric field that a dielectric can withstand without breakdown is called its dielectric strength. Its SI unit is Vm^{-1}.

86. In non-polar molecules, each molecule has no permanent dipole moment.
Here, all of these molecules, i.e. O_2, H_2 and N_2 are non-polar.

87. Potential energy of the proton increases, as it moves in opposite direction of electric field.

88. $\Delta V = -E \cdot \Delta x = -8.0 \times 10^4 \times 0.50$
$= -4 \times 10^4 \text{V}$

89. $\Delta U = q_0 \Delta V = 1.6 \times 10^{-19} \times (-4 \times 10^4)$
$= -6.4 \times 10^{-15} \text{J}$

90. As, $\Delta K = -\Delta U = 6.4 \times 10^{-15} \text{J}$
(from conservation of energy)

$\therefore \quad \Delta K = \frac{1}{2} m v_B^2$

$\Rightarrow \quad v_B = \sqrt{\frac{2\Delta K}{m}} = \sqrt{\frac{2 \times 6.4 \times 10^{-15}}{1.66 \times 10^{-27}}}$
$= 2.77 \times 10^6 \text{ m/s}$

91. Electrostatic potential energy of the system,
$U = 9 \times 10^9 \cdot \frac{q_1 q_2}{r}$
$= 9 \times 10^9 \times 1 \times 10^{-6} \times 1 \times 10^{-6}$
$= 9 \times 10^{-3} \text{J}$

03

Current Electricity

Quick Revision

1. **Electric Current** The rate of flow of charge is known as electric current. If ΔQ charge flows in time Δt, then current at any time t is

$$I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

Also, it can be expressed as

$$I = \frac{q}{t} = \frac{ne}{t} \qquad (\because\ q = ne)$$

The direction of current I is taken in the direction of flow of positive charge or opposite to the direction of flow of negative charge.

2. Electric current in terms of drift velocity,

$$I = neA\, v_d$$

where, n = number density of free electrons,
e = charge of an electron,
A = cross-sectional area of conductor
and v_d = drift velocity of an electron.

3. Current density at any point of conductor,

$$J = I/A = ne\, v_d$$

It is a vector quantity.

4. **Mobility of a Charge Carrier** It is defined as the magnitude of drift velocity of charge per unit applied electric field.

$$\mu = \frac{\text{Drift velocity}}{\text{Electric field}} = \frac{v_d}{E} = \frac{e\tau}{m}$$

where, m is mass of electron and τ is relaxation time.

5. **Ohm's Law** At constant temperature and other physical condition, the potential difference V across the ends of a given metallic wire (conductor) in a circuit is directly proportional to the current flowing through it.

$$V \propto I$$

or $$V = IR$$

where, R = resistance of conductor.

6. **Resistance** The opposition offered by the conductor in the flow of current, is called resistance, it is given as $R = \rho \dfrac{l}{A}$, where ρ is the resistivity.

7. **Resistivity** Resistivity of a material is equal to resistance per unit length per unit area.
Resistivity of material is given as, $\rho = \dfrac{m}{ne^2\tau}$
where, τ = relaxation time
and m = mass of the electron.
Specific resistance or resistivity depends on the nature of the material of conductor and temperature of conductor. It does not depend on the length (l) and cross-sectional area (A), i.e. geometry of conductor.

8. If a conductor is stretched to n-times of its original length, i.e. $l' = nl$, then

$$\Rightarrow \qquad R' = n^2 R$$

where, R' is the new resistance and R is the original resistance.

9. Relationship between current density (J), electric field (E) and conductivity (σ) is $J = \sigma E$.

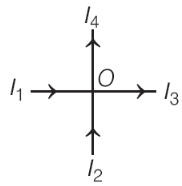
10. Temperature coefficient of resistance is given by

$$\alpha = \frac{R_2 - R_1}{R_1 (T_2 - T_1)}$$

where, R_1 = resistance at initial temperature,
R_2 = resistance at final temperature
and T_1 & T_2 = initial & final temperatures.

11. **Superconductivity** The resistivity of certain metals or alloy drops to zero, when they are cooled below a certain temperature is called critical temperature. This property of conductor is called **superconductivity**.
12. **Electrical Energy** is defined as the total work done by the source of emf (E) in maintaining the electric current (I) in the given circuit for a specified time t.
$$E = VI\,t = I^2R\,t = \frac{V^2t}{R}$$
Its SI unit is joule (J).
13. **Electrical Power** is defined as the rate of electrical energy supplied per unit time to maintain flow of electric current through a conductor.
$$P = VI = I^2\,R = \frac{V^2}{R}$$
Its SI unit is watt (W).
14. **Electromotive Force (EMF) of Cell** The maximum potential difference between the two poles or terminals of the cell in an open circuit is called the electromotive force (emf) of the cell. It is denoted by E and its SI unit is volt (V).
$$E = \frac{W}{q}$$
15. **Internal Resistance** is the resistance offered by the electrolyte of the cell due to the motion of charge through it and is denoted by r.
16. The relationship between r, R, E and V,
$$r = R\left(\frac{E}{V} - 1\right)$$
where, r = internal resistance,
R = external resistance,
E = emf of cell
and V = terminal potential difference of cell.
Also, $V = E - Ir$ $\left(\because I = \frac{V}{R}\right)$
and $V = \left(\frac{E}{R+r}\right)R = \frac{E}{\left(1+\frac{r}{R}\right)}$
17. During the charging of the cell,
$$V = E + Ir$$
So, if $V < E$, then current is drawn from the cell, i.e. discharging.
And if $V > E$, then charging of cell takes place.
18. **Combination of Cells**
    - **Series Combination** The equivalent emf of series combination is given by
    $$E = E_1 + E_2$$
    Equivalent resistance, $r = r_1 + r_2$
    If polarity of one of the batteries is reversed, then equivalent emf $|E_1 - E_2|$ and net internal resistance continue to be the same.
    i.e. $r_{eq} = r_1 + r_2$
    - **Parallel Combination** The equivalent emf of parallel combination is given by
    $$E_{eq} = \frac{E_1r_2 + E_2\,r_1}{r_1 + r_2}$$
    and internal resistance of combination,
    $$r_{eq} = \frac{r_1\,r_2}{r_1 + r_2}$$
    - **Mixed Grouping** It consists of m rows in parallel combination such that each row contains n cells each of emf E and internal resistance r, then current in the circuit is given by $I = \frac{mn\,E}{mR + nr}$
    and maximum current is drawn from the battery, when external resistance is equal to net internal resistance, i.e. $R = \frac{nr}{m}$
    and $$I_{max} = \frac{nE}{2\left(\frac{nr}{m}\right)} = \frac{m\,nE}{2nr} = \frac{mE}{2r}$$
19. **Kirchhoff's First Law or Junction Law** The algebraic sum of electric currents at any junction of electric circuit is equal to zero,
i.e. the sum of current entering into a junction O is equal to the sum of current leaving the junction.
i.e. $\Sigma I = 0$
$$I_1 + I_2 + (-I_3) + (-I_4) = 0$$
$$I_1 + I_2 = I_3 + I_4$$

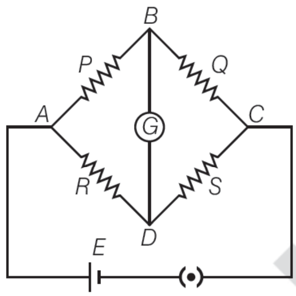
Junction law supports the law of conservation of charge because this is a point in a circuit that cannot act as a source or sink of charge.



20. **Kirchhoff's Second Law or Loop Law** In any closed mesh of electrical circuit, the algebraic sum of emfs of cells and the product of currents and resistances is always equal to zero. i.e. $\Sigma E + \Sigma IR = 0$

    Kirchhoff's second law supports the law of conservation of energy.

21. **Wheatstone Bridge** is an arrangement of four resistances connected to form the arms of quadrilateral *ABCD*. A battery with a key and galvanometer are connected along its two diagonals as shown in figure.

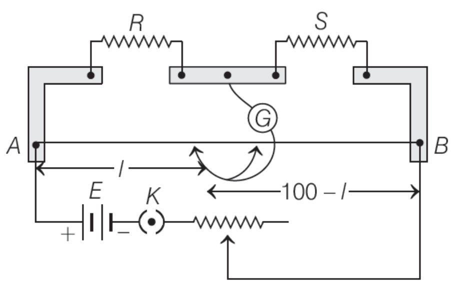


The bridge is said to be balanced, when $V_B = V_D$, there is no flow of current through galvanometer. i.e. $\dfrac{P}{Q} = \dfrac{R}{S}$

22. **Meter Bridge** is an electrical device used to determine the resistance and hence, specific resistance of material of given wire/conductor. It is based on the principle of balanced Wheatstone bridge.

    $\therefore$ For uniform wire,

    resistance of wire $\propto$ length of conductor

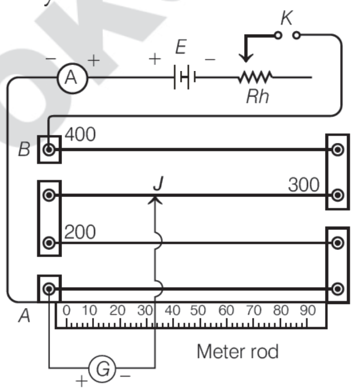


At balanced situation of bridge,

$$\frac{R}{S} = \frac{l}{(100-l)} \Rightarrow S = \left(\frac{100-l}{l}\right) \times R$$

where, l is the balancing length.

23. **Potentiometer** is an electrical device, which can
    - measure the potential difference with greater accuracy,
    - compare the emfs of two cells,
    - measure the emf of cell
    - and determine the internal resistance of a primary cell.



24. The potentiometer works on the principle that potential difference across any two points of uniform current carrying conductor is directly proportional to the length between the two points, i.e. $V \propto l$.

25. The emf's of two primary cells can be compared using potentiometer as $\dfrac{E_1}{E_2} = \dfrac{l_1}{l_2}$

    where, l_1 and l_2 are the balancing lengths corresponding to cells of emfs E_1 and E_2, respectively.

    Internal resistance of primary cell of emfs is given by

    $$r = R\left(\frac{l_1}{l_2} - 1\right)$$

    where, R = external resistance

26. **Potential Gradient** It is the potential drop per unit length of the wire of potentiometer, i.e. $K = \dfrac{V}{l}$, where V is potential difference applied by driving cell and l is length of potentiometer wire.

Objective Questions

Multiple Choice Questions

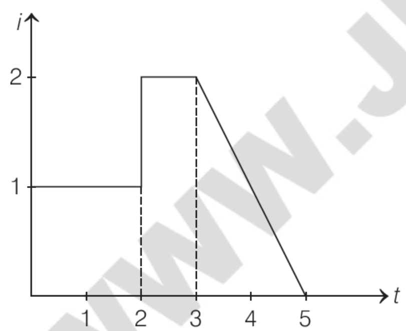
1. The current in a wire varies with time according to the equation $i = 4 + 2t$, where i is in ampere and t is in second. The quantity of charge which passes through a cross-section of the wire during the time $t = 2$ s to $t = 6$ s is

(a) 40 C (b) 48 C
(c) 38 C (d) 43 C

2. How many electrons pass through a lamp in 1 min, if the current is 300 mA? Given, the charge on an electron is 1.6×10^{-19} C.

(a) 1.125×10^{20} C (b) 1.875×10^{-18} C
(c) 1.875×10^{18} C (d) 1.125×10^{-20} C

3. The plot represents the flow of current through a wire at three different times.



The ratio of charges flowing through the wire at different times is

(a) 2 : 1 : 2 (b) 1 : 3 : 3
(c) 1 : 1 : 1 (d) 2 : 3 : 4

4. Drift velocity v_d varies with the intensity of electric field as per the relation.

(a) $v_d \propto E$ (b) $v_d \propto \frac{1}{E}$
(c) $v_d =$ constant (d) $v_d \propto E^2$

5. A metal wire is subjected to a constant potential difference. When the temperature of the metal wire increases, then the drift velocity of the electron in it

(a) increases and thermal velocity of the electron decreases
(b) decreases and thermal velocity of the electron decreases
(c) increases and thermal velocity of the electron increases
(d) decreases and thermal velocity of the electron increases

6. The drift velocity of the electrons in a copper wire of length 2 m under the application of a potential difference of 220 V is 0.5 ms^{-1}. Their mobility (in m^2 V^{-1} s^{-1})

(a) 2.5×10^{-3}
(b) 2.5×10^{-2}
(c) 5×10^{2}
(d) 5×10^{-3}

7. Which of the following characteristics of electrons determines the current in a conductor? ***(NCERT Exemplar)***

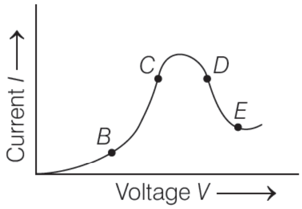
(a) Drift velocity alone
(b) Thermal velocity alone
(c) Both drift velocity and thermal velocity
(d) Neither drift nor thermal velocity

8. If charges move without collisions through the conductor, their kinetic energy would also change, so that the total energy is

(a) changed (b) unchanged
(c) doubled (d) halved

9. Graph showing the variation of current *versus* voltage for a material GaAs is shown in the figure.

Identify the region, where Ohm's law is obeyed.

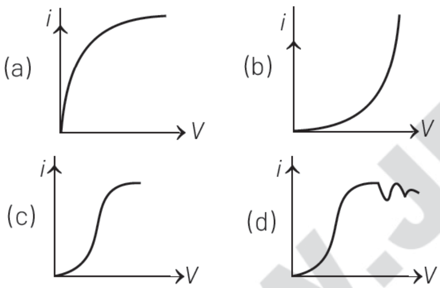


(a) CD (b) BC
(c) DE (d) None of these

10. Ohm's law in point form in field theory can be expressed as

(a) $R = \rho \frac{l}{A}$ (b) $J = \sigma E$
(c) $J = \frac{E}{\sigma}$ (d) $V = RI$

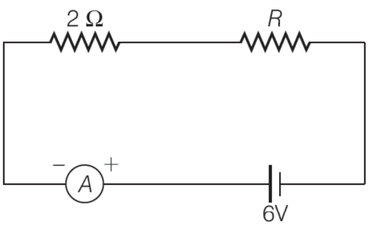
11. The variation between V-i for heating filament is shown by which graph?



12. The resistance of a wire is R ohm. If it is melted and stretched to n times its original length, its new resistance will be

(a) nR (b) $\frac{R}{n}$ (c) n^2R (d) $\frac{R}{n^2}$

13. If an ammeter in the given circuit shown in the diagram reads 2A, the resistance R is ***(CBSE SQP 2020)***

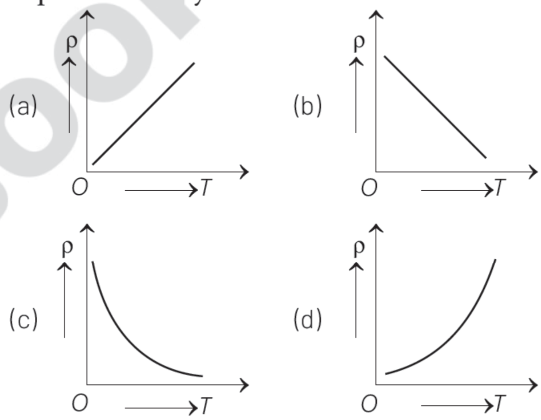


(a) 1Ω (b) 2Ω
(c) 3Ω (d) 4Ω

14. At room temperature (27.0°C) the resistance of a heating element is 100 Ω. What is the temperature of the element, if the resistance is found to be 117 Ω, given that the temperature coefficient of the material of the resistor is 1.70×10^{-4}/°C.

(a) 27°C (b) 1027°C (c) 17°C (d) 117°C

15. The temperature (T) dependence of resistivity (ρ) of a semiconductor is represented by



16. The temperature coefficient of resistance of an alloy used for making resistors is

(a) small and positive (b) small and negative
(c) arge and positive (d) large and negative

17. The electrical conductivity of the metal decreases with temperature, because

(a) the energy of the electrons increases with temperature
(b) a metal expands on heating
(c) the atoms of the metal vibrate more at higher temperature
(d) metals have low specific heat

18. Electric field and current density have relation

(a) $E \propto J$ (b) $E \propto J^2$
(c) $E \propto \frac{1}{J^2}$ (d) $E^2 \propto \frac{1}{J}$

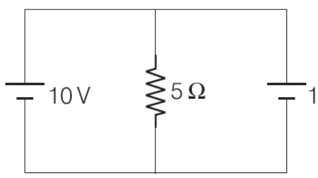
19. Two bulbs of 40W and 60W are connected to 220V line, the ratio of resistance will be

(a) 4 : 3 (b) 3 : 4 (c) 2 : 3 (d) 3 : 2

20. The heat produced by 100W heater in 2 min is equal to ***(CBSE SQP 2020)***

(a) 10.5 kJ (b) 16.3 kJ (c) 12.0 kJ (d) 14.2 kJ

21. Current through the 5Ω resistor is



(a) 2A (b) 4A (c) zero (d) 1A

22. A battery of emf E has an internal resistance r. A variable resistance R is connected to the terminals of the battery. A current i is drawn from the battery. V is the terminal potential difference. If R alone is gradually reduced to zero, which of the following best describes i and V?

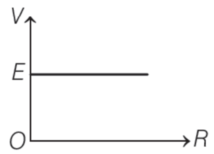
(a) i approaches zero, V approaches E

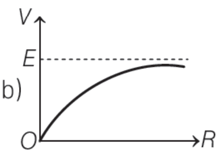
(b) i approaches $\frac{E}{r}$, V approaches zero

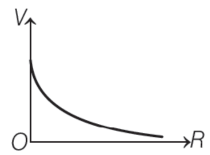
(c) i approaches $\frac{E}{r}$, V approaches E

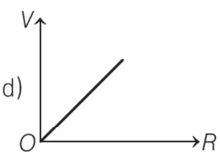
(d) i approaches infinity, V approaches E

23. A cell of emf (E) and internal resistance r is connected across a variable external resistance R. The graph of terminal potential difference V as a function of R is ***(CBSE Exam 2020)***

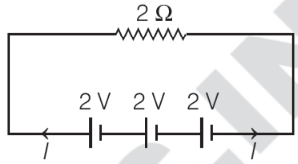
(a)


(b)


(c)


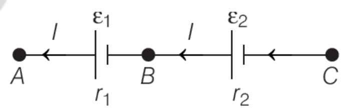
(d)


24. In the electric circuit shown, each cell has an emf of 2 V and internal resistance is $1\ \Omega$. The external resistance is $2\ \Omega$. The value of the current I is (in ampere)



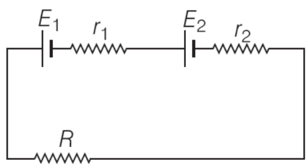
(a) 2 (b) 1.25
(c) 0.4 (d) 1.2

25. Consider first two cells in series as shown in figure. The potential difference between the terminals A and C of the combination is



(a) $V_{AC} = \varepsilon_1 - Ir_1$
(b) $V_{AC} = \varepsilon_2 - Ir_2$
(c) $V_{AC} = \varepsilon_{eq} - Ir_{eq}$
(d) $V_{AC} = 2\varepsilon_{eq} - Ir_{eq}$

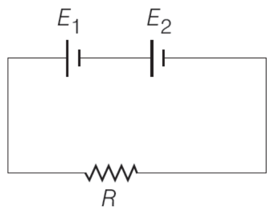
26. In the circuit shown in figure, $E_1 = 10$ V, $E_2 = 4$ V, $r_1 = r_2 = 1\Omega$ and $R = 2\Omega$. Find the potential difference across battery 1 and battery 2.



(a) 8.5 V, 5.5 V respectively
(b) 5.5 V, 8.5 V respectively
(c) 5.8 V, 5.5 V respectively
(d) 5.5 V, 5.8 V respectively

27. Under what conditions current passing through the resistance R can be increased by short circuiting the battery of emf E_2?

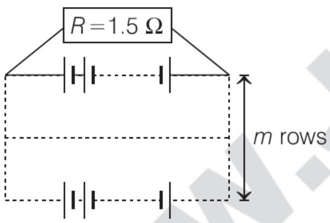
The internal resistances of the two batteries are r_1 and r_2, respectively.



(a) $E_2 r_1 > E_1(R + r_2)$
(b) $E_1 r_2 < E_2(R + r_1)$
(c) $E_2 r_2 < E_1(R + r_2)$
(d) $E_1 r_2 > E_2(R + r_1)$

28. 12 cells, each of emf 1.5 V and internal resistance of 0.5 Ω, are arranged in m rows each containing n cells connected in series, as shown in the figure.

Calculate the values of n and m for which this combination would send maximum current through an external resistance of 1.5 Ω.



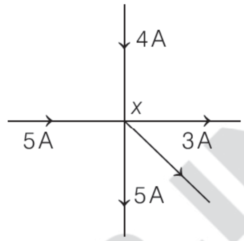
(n cells in each row)

(a) $n = 6, m = 2$
(b) $n = 2, m = 6$
(c) $n = 2, m = 2$
(d) $n = 3, m = 2$

29. According to Kirchhoff's current law as applied to a junction in a network of conductors

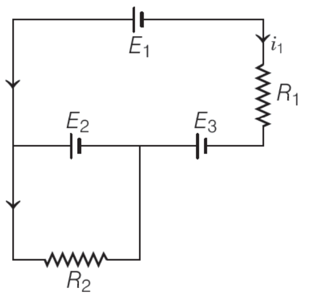
(a) total sum of currents meeting at junction is zero
(b) no current can leave the junction without some current entering it
(c) net current flow at the junction is positive
(d) algebraic sum of the currents meeting at the junction is zero

30. Five conductors are meeting at a point x as shown in the figure. What is the value of current in fifth conductor?



(a) 3A away from x (b) 1A away from x
(c) 4A away from x (d) 1A towards x

31. The currents i_1 and i_2 through the resistors R_1 $(= 10\ \Omega)$ and R_2 $(= 30\ \Omega)$ in the circuit diagram with $E_1 = 3$ V, $E_2 = 3$ V and $E_3 = 2$ V are respectively,

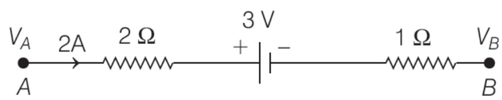


(a) 0.2 A, 0.1 A (b) 0.4 A, 0.2 A
(c) 0.1 A, 0.2 A (d) 0.2 A, 0.4 A

32. The algebraic sum of voltages around any closed path in a network is equal to

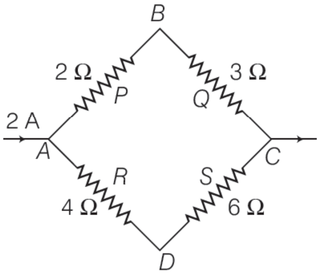
(a) infinity
(b) 1
(c) 0
(d) negative polarity

33. The potential difference $(V_A - V_B)$ between the points A and B in the given figure is



(a) −3 V (b) +3 V (c) +6 V (d) +9 V

34. If 2 A current is flowing in the shown circuit, then potential difference $(V_B - V_D)$ in balanced condition is

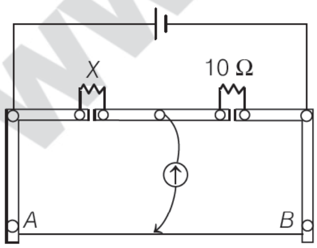


(a) 12 V (b) 6 V
(c) 4 V (d) zero

35. In a Wheatstone bridge circuit, $P = 7\,\Omega$, $Q = 8\,\Omega$, $R = 12\,\Omega$ and $S = 7\,\Omega$. Find the additional resistance to be used in series with S, so that the bridge is balanced.

(a) 6.72 Ω (b) 7.62 Ω
(c) 2.67 Ω (d) 6.27 Ω

36. A meter bridge is set up as shown in figure, to determine an unknown resistance X using a standard 10 Ω resistor. The galvanometer shows null point when tapping key is at 52 cm mark. The end-corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of X is

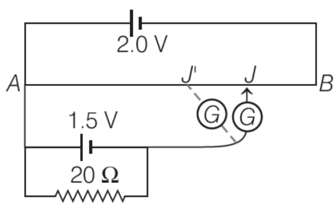


(a) 10.2 Ω (b) 10.6 Ω
(c) 10.8 Ω (d) 11.1 Ω

37. A resistance R is to be measured using a meter bridge, student chooses the standard resistance S to be 100Ω. He finds the null point at $I_1 = 2.9$ cm. He is told to attempt to improve the accuracy.
Which of the following is a useful way?
(NCERT Exemplar)

(a) He should measure l_1 more accurately
(b) He should change S to 1000Ω and repeat the experiment
(c) He should change S to 3Ω and repeat the experiment
(d) He should given up hope of a more accurate measurement with a meter bridge

38. The figure below shows a 2.0 V potentiometer used for the determination of internal resistance of a 2.5 V cell. The balance point of the cell in the open circuit is 75 cm. When a resistor of 10 Ω is used in the external circuit of the cell, the balance point shifts to 65 cm length of potentiometer wire. The internal resistance of the cell is



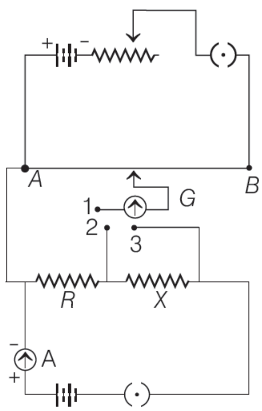
(a) 2.5 Ω
(b) 2.0 Ω
(c) 1.54 Ω
(d) 1.0 Ω

39. Two cells of emfs approximately 5 V and 10 V are to be accurately compared using a potentiometer of length 400 cm.
(NCERT Exemplar)

(a) The battery that runs the potentiometer should have voltage of 8V
(b) The battery of potentiometer can have a voltage of 15 V and R adjusted so that the potential drop across the wire slightly exceeds 10 V
(c) The first portion of 50 cm of wire itself should have a potential drop of 10 V
(d) Potentiometer is usually used for comparing resistances and not voltages

40. A potentiometer circuit is set up as shown. The potential gradient across the potentiometer wire, is k volt/cm and the ammeter, present in the circuit, reads 1.0 A when two way key is switched off. The balance points, when the key between the terminals (i) 1 and 2 (ii) 1 and 3, is plugged in, are found to be at lengths l_1 cm and l_2 cm, respectively.

The magnitudes of the resistors R and X in ohm, are then, respectively equal to



(a) $k(l_1 - l_2)$ and kl_2
(b) kl_1 and $k(l_2 - l_1)$
(c) $k(l_2 - l_1)$ and kl_2
(d) kl_1 and kl_2

41. 10 A current passes through a copper. The net charge after 5s in the wire is ....

(a) 2 C (b) 50 C
(c) 0.5 C (d) 0 C

42. Au is a highly conductive metal which obeys Ohm's law but .... does not obey Ohm's law due to lack of conduction electrons.

(a) Si
(b) Ge
(c) Both (a) and (b)
(d) None of the above

43. During charging of a cell terminal voltage is .... than emf of cell.

(a) smaller
(b) greater
(c) same
(d) zero

44. The connections between resistors in a meter bridge are made of thick copper strips because thick copper strips have ....

(a) high temperature tolerance
(b) high resistance
(c) low resistance
(d) low conductivity

45. Long wire of the potentiometer gives lower value of .... which increases sensitivity of potentiometer.

(a) resistance
(b) potential gradient
(c) electric potential
(d) heat dissipation

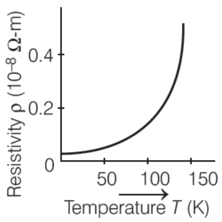
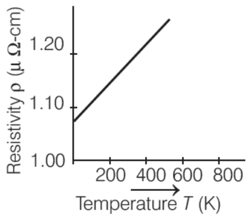
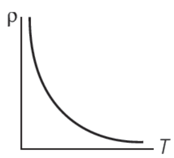
46. Which of the following statement is correct when power delivered by a battery is maximum?

(a) Internal resistance is equal to external resistance.
(b) Internal resistance is greater than external resistance.
(c) Internal reistance is less than external resistance.
(d) None of the above

47. Choose the correct statement.

(a) Kirchhoff's first law of electricity is based on conservation of charge while the second law is based on conservation of energy.
(b) Kirchhoff's first law of electricity is based on conservation of energy while second law is based on conservation of charge.
(c) Kirchhoff's both laws are based on conservation of charge.
(d) Kirchhoff's both laws are based on conservation of energy.

48. Match the Column I (graph) with Column II (relation) and select the correct answer from the codes given below.

	Column I		Column II
A.		p.	Temperature dependence of resistivity for a typical semiconductor.
B.		q.	Resistivity ρ of copper as a function of temperature T.
C.		r.	Resistivity ρ of nichrome as a function of absolute temperature T.

Codes

	A	B	C
(a)	r	q	p
(b)	q	p	r
(c)	q	r	p
(d)	r	p	q

Assertion/Reasoning MCQs

For question numbers 49 to 60, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

49. Assertion A wire carrying an electrical current has no electric field inside it.

Reason Rate of flow of electrons in one direction is equal to the rate of flow of protons in opposite direction.

50. Assertion In electrostatics, all charges whether free or bound are considered to be at rest.

Reason The charges in motion constitute an electric current.

51. Assertion A current flows in a conductor only when there is an electric field within the conductor.

Reason The drift velocity of electrons in presence of electric field decreases.

52. Assertion Charge carriers do not move with acceleration but with a steady drift velocity.

Reason Charge carriers undergo collisions with ions and atoms during transit.

53. Assertion Manganin and constantan are widely used in standard resistors.

Reason For manganin and constantan resistance, values would change very little with temperature.

54. Assertion If a current is flowing through a conducting wire of non-uniform cross-section, drift speed and resistance both will increase at a section where cross-sectional area is loss.

Reason Current density at such sections is more, where cross-sectional area is less.

55. **Assertion** The drift velocity of electrons in a metallic wire decreases, when temperature of the wire increases.

Reason On increasing temperature, conductivity of metallic wire decreases.

56. **Assertion** The average time of collisions τ decreases with increasing temperature.

Reason At increased temperature, average speed of the electrons, which act as the carriers of current increases, resulting in more frequent collisions.

57. **Assertion** If we bend an insulating wire, the resistance of the wire increases.

Reason The drift velocity of electron in bended wire does not remains same.

58. **Assertion** Bulb generally get fused when they are switched ON or OFF.

Reason When we switch ON or OFF, a circuit current changes it rapidly.

59. **Assertion** Terminal voltage of a cell is greater than emf of cell during charging the cell.

Reason The emf of a cell is always greater than its terminal voltage.

60. **Assertion** A potentiometer is preferred over a voltmeter for measurement of a cell.

Reason Potentiometer does not draw any current from the cell.

Case Based MCQs

Direction *Answer the questions from 61-65 on the following case.*

Resistance and Resistivity

The materials can be classified as conductors, semiconductors and insulators depending on their resistivities, in an increasing order of their values. Metals have low resistivities in the range of 10^{-8} Ωm to 10^{-6} Ωm. At the other end are insulators like ceramic, rubber and plastics having resistivities 10^{18} times greater than metals or more. In between these two are the semiconductors. These however, have resistivities characteristically decreasing with a rise in temperature. The resistivities of semiconductors can be decreased by adding small amount of suitable impurities. This last feature is exploited in use of semiconductors for electronic devices.

Commercially produced resistors for domestic use or in laboratories are of two major types: wire bound resistors and carbon resistors.

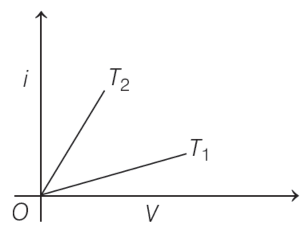
61. In the increasing range of temperature 300-400 K, the resistance of Cu and Si respectively.

(a) Linear increase for Cu, linear increase for Si
(b) Linear increase for Cu, exponential increase for Si
(c) Linear increase for Cu, exponential decrease for Si
(d) linear decrease for Cu, linear decrease for Si

62. Which of the following material can be used for heating purpose in electric geyser?

(a) Copper (b) Aluminium
(c) Gold (d) Nichrome

63. The i-V graph for material is given at two different temperatures. The correct relation between T_1 and T_2 is



(a) $T_1 > T_2$ (b) $T_1 < T_2$
(c) $T_1 = T_2$ (d) $T_1 = 2T_2$

64. Resistance of a wire at 20°C is 20 Ω and at 500°C is 60Ω. At what temperature, its resistance is 25Ω?

(a) 160°C (b) 250°C
(c) 100°C (d) 80°C

65. Product of resistivity and conductivity of a conductor depends on

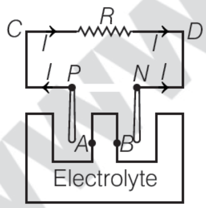
(a) cross-section (b) temperature
(c) length (d) None of these

Direction *Answer the questions from 66-70 on the following case.*

EMF of a Cell

An electric cell is a source of energy that maintains a continuous flow of charge in a circuit. It changes chemical energy into electrical energy. It has two electrodes, positive electrode and negative electrode as shown below.

Electric cell has to do some work in maintaining the current through a circuit. The work done by the cell in moving unit positive charge through the whole circuit (including the cell) is called the electromotive force (emf) of the cell.



66. When two electrodes (positive and negative) of a cell are immersed in an electrolytic solution, the charges are exchanged between

(a) positive electrode and electrolyte only
(b) negative electrode and electrolyte only
(c) both electrodes and electrolytes
(d) directly between two electrodes

67. The current flowing in the cell is

(a) $I=\frac{\varepsilon}{R+r}$ (b) $I=\frac{R+r}{\varepsilon}$ (c) $I=\frac{R}{\varepsilon}$ (d) $I=\frac{r}{\varepsilon}$

68. The maximum current that can be drawn from a cell is for

(a) $R=$ infinity
(b) $R=$ finite non-zero resistance
(c) $R=0$
(d) $R=r$

69. When R is infinite, then potential difference V between P and N is

(a) ε (b) 2ε (c) $\frac{\varepsilon}{2}$ (d) $\frac{\varepsilon}{4}$

70. For the given circuit, if the cell has an emf of 2V and the internal resistance of this cell is 0.1 Ω, it is connected to resistance of 3.9 Ω, the voltage across the cell will be

(a) 1.95 V (b) 1.5 V (c) 2 V (d) 1.8 V

Direction *Answer the questions from 71-75 on the following case.*

Commercial Electrical Energy

An electrical appliance uses a lot of electric energy when it is operated e.g., geysers heaters etc. The electrical energy consumed is dependent on the time for which a specific appliance of fixed power rating is used.

However, the energy used in hour is denoted as $1\text{ kWh} = 3.6\times10^{6}$ joule.
This is represented as 1 unit. Different electrical appliance have difference power consumption which is mentioned on the device clearly.

71. A bulb is rated 60 W, 220 V. It signifies

(a) it consumes 60 J power per second
(b) it consumes 220 V power per second
(c) it has 60 W energy
(d) None of the above

72. Which of the following does not represent electrical power?

(a) $\frac{V^2}{R}$ (b) I^2R
(c) VI (d) $\frac{I^2}{V}$

73. Two electric bulbs P and Q having resistances ratio 1 : 2 will consume power in the ratio

(a) 1 : 2 (b) 2 : 1
(c) 1 : 4 (d) 4 : 1

74. An electric heater consumes 1.5 kW power. If it used everyday for 2 hours, then electric energy used in January is

(a) 90 unit (b) 92 unit
(c) 93 unit (d) 95 unit

75. The wires used in heating element are different than the connecting wires. The connecting wires uses copper but heating element does not because

(a) copper is expensive
(b) copper heats very fast
(c) copper is poor conductor of heat
(d) copper has very low resistivity

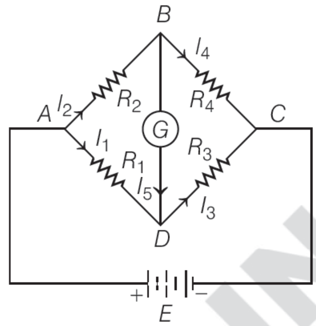
Direction *Answer the questions from 76-80 on the following case.*

Wheatstone Bridge

In 1845 by German physicist Gustav Kirchhoff described Kirchhoff's circuit laws which are two equalities that deal with the current and potential difference (commonly known as voltage) in the lumped element model of electrical circuits.

As an application of these laws, consider the circuit shown below, which is called the Wheatstone bridge. This bridge consists of four resistors R_1, R_2, R_3 and R_4. Across one pair of diagonally opposite points (A and C in the figure) a source is connected.

This (i.e., AC) is called the battery arm. Between the other two vertices, B and D, a galvanometer G (which is a device to detect currents) is connected. This line, shown as BD in the figure, is called the galvanometer arm. Of special interest, is the case of a balanced bridge where the resistors are such that $I_g = 0$.



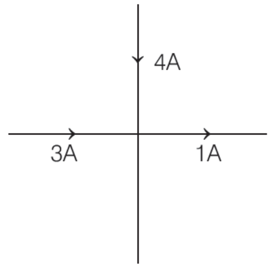
76. Wheatstone bridge can help us to determine the resistance of a

(a) known resistor (b) unknown resistor
(c) Both (a) and (b) (d) None of these

77. Kirchhoff's junction rule is a consequence of conservation of

(a) momentum (b) mass
(c) energy (d) charge

78. Three wires meet at a node as given in figure. The current in the fourth wire will be



(a) 2A, incoming (b) 2A, outgoing
(c) 6A, incoming (d) 6A, outgoing

79. Which instrument is used as the null detector in the Wheatstone bridge?

(a) Voltmeter
(b) Ammeter
(c) Galvanometer
(d) Multimeter

80. The value of X when the Wheatstone network is balanced if $R_1 = 500\,\Omega$, $R_2 = 800\,\Omega$, $R_3 = X + 400\,\Omega$, $R_4 = 1000\,\Omega$ would be

(a) $200\,\Omega$ (b) $220\,\Omega$
(c) $225\,\Omega$ (d) $240\,\Omega$

ANSWERS

Multiple Choice Questions

1. (b)	2. (a)	3. (c)	4. (a)	5. (d)	6. (d)	7. (a)	8. (b)	9. (b)	10. (b)
11. (a)	12. (c)	13. (a)	14. (b)	15. (c)	16. (a)	17. (a)	18. (a)	19. (d)	20. (c)
21. (a)	22. (b)	23. (b)	24. (d)	25. (c)	26. (a)	27. (d)	28. (a)	29. (d)	30. (b)
31. (a)	32. (c)	33. (d)	34. (d)	35. (a)	36. (b)	37. (c)	38. (c)	39. (b)	40. (b)
41. (d)	42. (c)	43. (b)	44. (c)	45. (b)	46. (a)	47. (a)	48. (c)		

Assertion/Reasoning MCQs

49. (c)	50. (b)	51. (c)	52. (a)	53. (a)	54. (b)	55. (b)	56. (a)	57. (d)	58. (a)
59. (c)	60. (a)								

Case Based MCQs

61. (c)	62. (d)	63. (a)	64. (d)	65. (d)	66. (c)	67. (a)	68. (d)	69. (a)	70. (a)
71. (a)	72. (d)	73. (b)	74. (c)	75. (d)	76. (c)	77. (d)	78. (d)	79. (c)	80. (c)

SOLUTIONS

1. The instantaneous charge,

$$dq = i\,dt = (4 + 2t)dt$$
$$q = \int_2^6 (4 + 2t)\,dt$$
$$= [4t + t^2]_2^6$$
$$= [4 \times 6 + 6^2] - [4 \times 2 + 2^2]$$
$$= 60 - 12 = 48 \text{ C}$$

2. Given, $i = 300$ mA

$$= 300 \times 10^{-3} \text{A}$$
$$e = 1.6 \times 10^{-19} \text{ C}$$
$$t = 1 \text{ min} = 60 \text{ s}$$

Charge passing in 1 min,

$$q = i \times t$$

Let n electron pass in 1 min,

$$\therefore \quad n = \frac{q}{e}$$
$$= \frac{i \times t}{e}$$
$$= \frac{300 \times 10^{-3} \times 60}{1.6 \times 10^{-19}}$$
$$= 1.125 \times 10^{20} \text{ C}$$

3. Since, charge (q) = current $(i) \times$ time (t)

Therefore, charge is equal to area under the curve.

$\therefore$ Ist rectangle $= q_1 = lb = 2 \times 1 = 2$

IInd rectangle $= q_2 = lb = 1 \times 2 = 2$

IIIrd triangle $= q_3 = \frac{1}{2} lb = \frac{1}{2} \times 2 \times 2 = 2$

Hence, ratio $q_1 : q_2 : q_3 = 1:1:1$.

4. Drift velocity,

$$v_d = \frac{e}{m} \times \frac{V}{l} \tau \text{ or } v_d = \frac{e}{m} \cdot \frac{El}{l} \tau \quad (\because V = El)$$

$\therefore \quad v_d \propto E$

5. With rise in temperature, the thermal velocity of the electron increases due to increase in their thermal energy. As the result, the relaxation time decreases and hence drift velocity of charge carrier will also decrease because drift velocity is proportional to the relaxation time.

6. Drift velocity = mobility $\times$ intensity of electric field

or $v_d = \mu E$ or $\mu = \frac{v_d}{E}$

or $$\mu = \frac{v_d}{\frac{V}{l}} = \frac{v_d \times l}{V} \quad \left(\because E = \frac{V}{l}\right)$$

$$\therefore \quad \mu = \frac{0.5 \times 2}{220} = 4.5 \times 10^{-3}$$
$$= 5 \times 10^{-3} \text{ m}^2 \text{ V}^{-1} \text{ s}^{-1}$$

7. The relationship between current and drift speed is given by $I = neAv_d$

Here, I is the current and v_d is the drift velocity.

So, $I \propto v_d$

Thus, only drift velocity determines the current in a conductor.

8. When charge move without collisions through conductor, their kinetic energy would also change but the total energy remains constant.

9. BC is the region, where Ohm's law is obeyed because in this part, the current varies linearly with the voltage.

10. Since, the relation between the current flowing through conductor is given by

$$I = nAev_d$$

$$\Rightarrow \quad \frac{I}{A} = \frac{ne^2\tau E}{m} \quad \left(\because v_d = \frac{e\tau E}{m}\right)$$

$$\Rightarrow \quad J = \frac{1}{\rho} E \quad \left(\because J = \frac{I}{A}\right)$$

$$\Rightarrow \quad J = \sigma E \quad \left(\because \sigma = \frac{1}{\rho}\right)$$

This relation is a microscopic form of Ohm's law.

11. As the current in heating filament increases, it gets more heated.

Hence, its temperature increases and resistance also increases, due to which current decreases.

Since, Ohm's law does not follow at high temperatures. So, V-i graph given in option (a) is correct.

12. Volume of material remains same on stretching.

As volume remains same, $A_1 l_1 = A_2 l_2$

Now, given $l_2 = nl_1$

$\therefore$ New area, $A_2 = A_1 l_1 / l_2 = A_1 / n$

Resistance of wire after stretching,

$$R_2 = \rho \frac{l_2}{A_2} = \rho \frac{nl_1}{A_1 / n}$$
$$= \left(\rho \frac{l_1}{A_1}\right) n^2$$
$$= n^2 R \quad \left[\because R = \left(\rho \frac{l_1}{A_1}\right)\right]$$

13. By applying KVL in circuit,

$$6 = 2I + RI$$

Given, $I = 2\text{A}$

$$\Rightarrow \quad 2R = 6 - 4 \Rightarrow R = 1\,\Omega$$

14. Given, the resistance of heating element at temperature $27\,°\text{C} = R_{27} = 100\,\Omega$

Resistance of heating element at temperature $t\,°\text{C} = R_t = 117\,\Omega$

Temperature coefficient of resistance

$$\alpha = 1.70 \times 10^{-4}/°\text{C}$$

Temperature coefficient of resistance

$$\alpha = \frac{R_t - R_{27}}{R_{27}(t - 27)}$$

$$1.70 \times 10^{-4} = \frac{117 - 100}{100\,(t - 27)}$$

or $$t - 27 = \frac{17}{100 \times 1.70 \times 10^{-4}}$$

or $$t = 1000 + 27 = 1027\,°\text{C}$$

Thus, the temperature of element is 1027 °C when its resistance is 117 Ω.

15. The resistivity of a semiconductor decreases with increase in temperature exponentially.

Hence, option (c) is correct.

16. The temperature coefficient of resistance of an alloy used for making resistors is small and positive.

17. The electrical resistance arises due to the collisions of electrons with the lattice and other electrons in their paths. When temperature increases, the electrons move faster due to their increased kinetic energy. Thus, they collide more frequently with each other. Thereby, increasing the resistance. As, resistance is inversely proportional to the conductivity.

So, when the temperature of the metal increases electrical conductivity decreases.

18. Current density relates with electric field as

$$J = \sigma E \Rightarrow J \propto E$$

where, σ = conductivity.

19. Power, $P = \frac{V^2}{R}$

Given, $P_1 = 40$ W, $P_2 = 60$ W

$$\therefore \quad 40 = \frac{V^2}{R_1} \quad \ldots\text{(i)}$$

$$\text{and} \quad 60 = \frac{V^2}{R_2} \quad \ldots\text{(ii)}$$

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

$$\frac{40}{60} = \frac{R_2}{R_1} \quad \text{or} \quad \frac{R_1}{R_2} = \frac{3}{2} = 3:2$$

20. Given, power of heater, $P = 100$ W

Time, $T = 2$ min

$= 2 \times 60 = 120$ s

Heat produced, $h = Pt$

$$= 100 \times 120$$
$$= 1.2 \times 10^4 \text{ J}$$
$$= 12.0 \times 10^3 \text{ J}$$
$$= 12.0 \text{ kJ}$$

21. Potential difference $= 10$ V

Resistance $= 5\,\Omega$

So, $I = \frac{V}{R} = \frac{10}{5} = 2$ A

22. Current, $I = \frac{E}{R + r}$, when R decreases to 0,

$I = \frac{E}{r}$.

Similarly, potential difference $V = IR$ when R decreases to 0, $V = 0$.

23. Current flowing through cell, $I = \frac{E}{R + r}$

$$\therefore \quad \frac{V}{R} = \frac{E}{R + r} \quad \left(\because I = \frac{V}{R}\right)$$

$$\Rightarrow \quad V = E\left(\frac{R}{R + r}\right)$$

$$\Rightarrow \quad V = E\left(\frac{1}{1 + \frac{r}{R}}\right)$$

When $R = 0$, then

$$V = E\left(\frac{1}{1 + \infty}\right)$$

$$V = 0$$

When $R = \infty$, then

$$V = E\left(\frac{1}{1 + \frac{r}{\infty}}\right) = E\left(\frac{1}{1 + 0}\right)$$

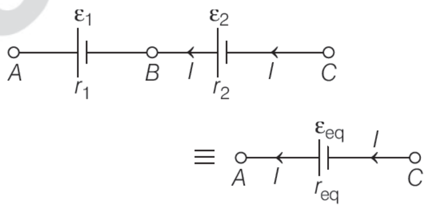
$$V = E$$

Hence, graph showing the variation between R and E is correctly shown in option (b).

24. Current $= \frac{\text{Net emf}}{\text{Net resistance}}$

$$\Rightarrow \quad I = \frac{2 + 2 + 2}{1 + 1 + 1 + 2} = \frac{6}{5} = 1.2 \text{ A}$$

25. The given circuits are as shown below

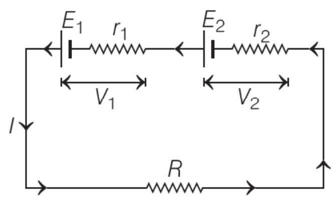


So, potential difference between the terminals A and C is,

$$V_{AC} = V_A - V_C = (V_A - V_B) + (V_B - V_C)$$
$$= \varepsilon_1 - Ir_1 + \varepsilon_2 - Ir_2$$
$$= (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2)$$
$$= \varepsilon_{eq} - Ir_{eq}$$

26. Net emf of the circuit

$$= E_1 - E_2$$
$$= (10 - 4) = 6 \text{ V}$$



Total resistance of the circuit

$$= R + r_1 + r_2 = 4\ \Omega$$

$\therefore$ Current in the circuit,

$$I = \frac{\text{Net emf}}{\text{Total resistance}} = \frac{6}{3} = 1.5 \text{ A}$$

Now, $V_1 = E_1 - Ir_1 = 10 - (1.5)(1) = 8.5$ V

and $V_2 = E_2 + Ir_2$

$= 4 + (1.5)(1) = 5.5$ V

27. Current, $i_1 = \dfrac{E_1 + E_2}{r_1 + r_2 + R}$ and $i_2 = \dfrac{E_1}{R + r_1}$

$i_2 > i_1$

$\therefore \dfrac{E_1}{R + r_1} > \dfrac{E_1 + E_2}{r_1 + r_2 + R}$

or $E_1 r_2 > E_2(R + r_1)$

28. For maximum current through the external resistance,

External resistance = Total internal resistance of cells

or $R = \dfrac{nr}{m}$

$\therefore 1.5 = \dfrac{n \times 0.5}{\frac{12}{n}}$ $(\because mn = 12)$

or $36 = n^2$

$\therefore n = 6$ and $m = 2$

29. Kirchhoff's first law states that, the algebraic sum of the currents meeting at a point in an electrical circuit is always zero. It is known as junction rule.

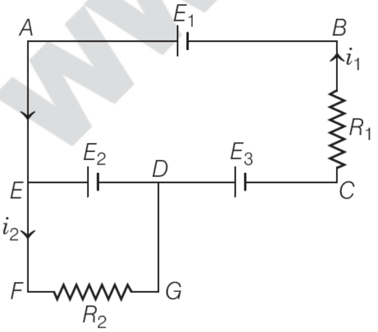
30. According to Kirchhoff's first law,

$(5\text{A}) + (4\text{A}) + (-3\text{A}) + (-5\text{A}) + I = 0$

$\Rightarrow I = -1$ A

So, current in fifth conductor is 1A flowing away from *x*.

31.



In closed loop *EFGDE*,

$i_2 R_2 = E_2$

$i_2 \times 30 = 3$

$i_2 = 0.1$ A

In closed loop *ABCEA*,

$-i_1 R_1 - E_1 + E_2 + E_3 = 0$

$-i_1 \times 10 - 3 + 3 + 2 = 0$

So, $i_1 = 0.2$ A

32. According to Kirchhoff's voltage rule, the algebraic sum of changes in potential voltage around any closed loop involving resistors and cells in the loop is zero.

33.

Applying KVL,

$V_A + \Sigma V = V_B + 2 \times 2 + 2 \times 1$

$V_A - V_B - 3 = 4 + 2$

$V_A - V_B = 9$ V

34. In Wheatstone bridge,

$\dfrac{P}{Q} = \dfrac{R}{S}$ or $\dfrac{2}{3} = \dfrac{4}{6} = \dfrac{2}{3}$

i.e. in the balanced condition, $V_B - V_D = 0$.

35. Let the bridge be balanced when additional resistance *x* is put in series with *S*.

Then, $(S + x) = \dfrac{Q}{P} R$

or $x = \dfrac{Q}{P}(R - S)$

$= \dfrac{8}{7} \times (12 - 7) = 6.72\,\Omega$

36. Given, standard resistance, $Y = 10\Omega$, balance length, $L_1 = 52$ cm and end-corrections, $x_1 = 1$ cm and $x_2 = 2$ cm. Now, balance length, $L_2 = 100 - L_1 = 100 - 52 = 48$ cm.

As, balance condition for meter bridge,

$$\frac{X}{(L_1 + x_1)} = \frac{Y}{(L_2 + x_2)}$$

$$\Rightarrow \frac{X}{(52 + 1)} = \frac{10}{(48 + 2)}$$

$$\Rightarrow X = \frac{10 \times 53}{50} = 10.6\,\Omega$$

37. The percentage error in R can be minimised by adjusting the balance point near the middle of the bridge, i.e. when I_1 is close to 50 cm. This requires a suitable choice of *S*.

Since, $\dfrac{R}{S} = \dfrac{R\, l_1}{R(100 - l_1)} = \dfrac{l_1}{100 - l_1}$

Since, here $R : S :: 2.9 : 97.1$ imply that the S is nearly 33 times to that of R. In ordered to make this ratio 1:1, it is necessary to reduce the value of S nearly $\frac{1}{33}$ times, i.e. nearly $3\,\Omega$.

38. For a potentiometer, the internal resistance r is given by $r = R\left(\frac{l_1}{l_2} - 1\right)$

Given, $R = 10\ \Omega$, $l_1 = 75$ cm, $l_2 = 65$ cm

$\therefore \quad r = 10\left(\frac{75}{65} - 1\right) = 10 \times 0.154 = 1.54\ \Omega$

39. In a potentiometer experiment, the emf of a cell can be measured, if the potential drop along the potentiometer wire is more than the emf of the cell to be determined. Here, values of emfs of two cells are given as 5 V and 10 V. Therefore, the potential drop along the potentiometer wire must be more than 10 V.

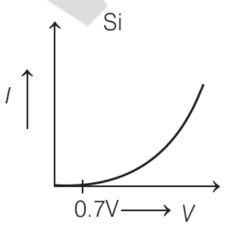
40. In the first case potential difference balance against resistance $R = k_1 l_1$

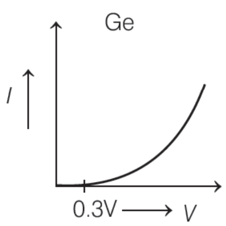
Potential difference against, $R + X = kl_1$

Potential difference over $X\,\Omega = k(l_2 - l_1)$

41. The amount of charge passing through a conductor per second is called magnitude of current, i.e. $i = \frac{Q}{t}$. The net charge on the wire remains constant or zero when the current is passed. Hence, the net charge after 5 s in the wire is 0C.

42. Si and Ge are semiconductors and current in such materials increases exponentially, hence they do not follow Ohm's law. The potential *versus* current of Si and Ge are given as,





43. During charging of a cell terminal voltage is greater than emf of the cell, i.e.

$$V = E + Ir$$

where, r is internal resistance and I is the current inside the battery while charging.

44. Copper strips are made thicker because thicker material of same length have low resistance.

$$R = \rho \frac{l}{A}$$

As, R is inversely proportional to area (A), so thick copper strips offer low resistance.

The fall in potential per unit length of the wire is called potential gradiant along the wire.

45. By increasing the length of connecting wire, the value of potential gradient is decreased.

The sensitivity of the potentiometer depends upon the potential gradiant.

46. Power delivered by the battery is maximum when its internal resistance equals to the external resistance.

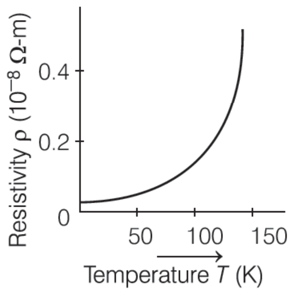
47. Kirchhoff's first law states that, the algebraic sum of currents meeting at a point in a circuit is zero.

It is based on conservation of charge.

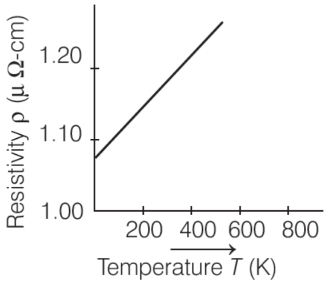
Kirchhoff's second law states that, the algebraic sum of potential difference around a closed loop is zero. It is based on the law of conservation of energy.

48. A. The relation of resistivity of a metal (like copper) with temperature is $\rho_T = \rho_0[1 + \alpha(T - T_0)]$.

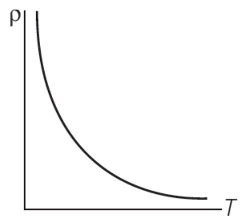
It implies that, a graph of ρ_T plotted against T would be a straight line. At temperature much lower than 0° C, the graph, however deviates considerably from a straight line as shown in figure below



B. Some materials like nichrome, exhibit a very weak dependence of resistivity with temperature as shown in figure below



C. Unlike metals, the resistivities of semiconductors decreases with increasing temperatures. Its dependence is as shown in figure below



Hence, A $\rightarrow$ q, B $\rightarrow$ r and C $\rightarrow$ p.

49. As many electrons enter from one end of the wire and move out from the other end. There is no net charge on the wire and so there is no electric field inside it.

Only in liquid and gas conductor, rate of flow of electrons in one direction is equal to the rate of flow of protons in opposite direction.

Therefore, A is true but R is false.

50. In electrostatics, all charges whether free or bound are considered to be at rest.

But net charges in motion constitute an electric current.

Therefore, both A and R are true but R is not the correct explanation of A.

51. In the absence of external electric field, the free elctrons move randomly in the conductor, so their drift velocity is zero and therefore no current in the circuit.

As soon as the electric field is set up within the conductor, electrons start drifting in its opposite direction but the electrons begin to gain drift velocity only in the presence of external electric field.

Therefore, A is true but R is false.

52. Charge carriers do not move with acceleration but with a steady drift velocity.

This is because of the collisions with ions and atoms during transit.

Therefore, both A and R are true and R is the correct explanation of A.

53. Manganin and constantan have very low temperature coefficient of resistance. So, their resistance values change very little with temperature. This is the reason, they are widely used in standard resistors.

Therefore, both A and R are true and R is the correct explanation of A.

54. Drift speed is given by

$$v_d = \frac{I}{n e A} \qquad (\because I = n e A v_d)$$

$$\Rightarrow \quad v_d \propto \frac{1}{A}$$

Resistance, $R = \frac{\rho l}{A}$

$$R \propto \frac{1}{A}$$

Therefore, drift speed and resistance both will increase at section, where cross-section area is loss.

On the other hand, current density is $J = \frac{I}{A}$

$$\Rightarrow \quad J \propto \frac{1}{A}$$

Therefore, both A and R are true but R is not the correct explanation of A.

55. On increasing the temperature of a conductor, the kinetic energy of free electrons increases.

On account of this, they collide more frequently with each other (and with the ions of the conductor) and consequently their drift velocity decreases.

On increasing temperature, conductivity of metallic wire decreases.

Therefore, both A and R are true but R is not the correct explanation of A.

56. With increase in temperature, average speed of the electrons, which acts as the carriers of current increases, resulting in more frequent collisions.

Thus, the average time of collisions τ decreases with increasing temperature.

Therefore, both A and R are true and R is the correct explanation of A.

57. Bending will not increases the resistance of the conducting wire.

Also, drift velocity of electron is independent of bending of conductor, i.e. it remains same.

Therefore, A is false and R is also false.

58. Switching results in high decay/growth rate of current which results in a high current when bulb is turned ON or OFF.

So, a bulb is most likely to get fused when it is just turned ON or OFF.

Therefore, both A and R are true and R is correct explanation of A.

59. During charging, $E = V + Ir$, in case of charging, emf of a cell is less than its terminal voltage while in case of discharging emf is greater than terminal voltage.

Therefore, A is true but R is false.

60. When a voltmeter is connected across the two terminals of a cell, it draws a small current from the cell. So, it measures terminal potential difference between the two terminals of the cell. Whereas, when a potentiometer is used for the measurement of emf of a cell, it does not draw any current from cell.

So, potentiometer is preferred over that of a voltmeter for measurement of a cell.

Therefore, both A and R are true and R is the correct explanation of A.

61. For conductive metals (Cu) the resistance increases with increase in temperature with linear relationship, i.e. $r = r_0(1 + \alpha T)$, where α is coefficient fixed for a material.

In semiconductor (Si), the resistance decrease exponentially as there is a breaking of covalent bond which generates electron hole pairs. This increases conductivity as $\sigma = Ce^{\frac{-En}{2kT}}$.

62. Nichrome is a non-magnetic alloy of nickel and chromium. It is the most common resistance wire for heating purpose because it has a high resistivity and it oxidises at high temperature.

63. Slope of the graph will give us the reciprocal of resistance. Here resistance at temperature T_1 is greater than T_2. Since, resistance of metallic wire is more at higher temperature than at lower temperature, hence $T_1 > T_2$.

64. Given; $R_T = 60\ \Omega$, $T = 500°C$

$$R_0 = 20\ \Omega,\ T' = 20°C$$

Resistance at given temperature,

$$R_T = R_0[1 + \alpha(T - T')]$$

$$\therefore \quad 60 = 20[1 + \alpha(500 - 20)]$$

$$\Rightarrow \quad \alpha = \frac{2}{480} = 0.00417$$

Now, $\quad R' = 25\,\Omega$, $T'' = ?$

$$R' = R_0[1 + \alpha(T'' - T')]$$

$$\therefore \quad 25 = 20[1 + (0.00417)(T'' - 20)]$$

$$\Rightarrow \quad T'' = 80°\ C$$

65. As we know that, resistivity is reciprocal of conductivity. Hence, $\rho = \frac{1}{\sigma}$.

Hence, product of resistivity and conductivity of any conductor is 1.

66. When two electrodes are immersed in an electrolytic solution, the charges are exchanged between the electrodes and the electrolytes. Charges flow from higher reduction potential to lower reduction potential and hence circuit is completed.

67. The load resistance and internal resistance are in series, hence same amount of current flows through both of the resistor. The terminal potential ε is given by

$$\varepsilon = IR + Ir$$

$$I(R + r) = \varepsilon$$

$$I = \frac{\varepsilon}{R + r}$$

68. Maximum current can be drawn out from a cell is when internal resistance is equal to the load resistance is $R = r$.

69. If $R = \infty$, then no current flows in the circuit.

Hence, terminal potential is equal to emf of the cell, i.e. $V = \varepsilon$.

70. Given, emf, $\varepsilon = 2V$

Internal resistance, $r = 0.1\ \Omega$

Load resistance, $R = 3.9\ \Omega$

Terminal voltage, $V = ?$

Terminal voltage, $V = \varepsilon - Ir$

$$V = \varepsilon - \left(\frac{\varepsilon}{R + r}\right) r$$

$$V = 2 - \left(\frac{2}{3.9 + 0.1}\right) \times 0.1$$

$$V = 2 - 0.05 = 1.95 \text{ V}$$

71. A bulb rated 60 W, 220 V will consume 60 J energy per second if it is operated at 220 V.

72. $\frac{I^2}{V}$ does not represent electrical power. Rest all options are formulae of electrical power

i.e. power $= \frac{V^2}{R} = I^2 R = VI$

73. Given, $\frac{R_P}{R_Q} = \frac{1}{2}$

$\Rightarrow \quad R_Q = 2R_P$

Power $(P) = \frac{V^2}{R}$ $\quad (\because V \text{ is constant})$

$$P_P = \frac{V^2}{R_P} \quad \ldots(i)$$

$$P_Q = \frac{V^2}{R_Q} \quad \ldots(ii)$$

Dividing Eq. (i) by Eq. (ii), we get

$$\frac{P_P}{P_Q} = \frac{V^2}{R_P} \times \frac{2R_P}{V^2}$$

$$P_P = 2P_Q$$

Hence, bulb P will consume two times the power of bulb Q. Thus, ratio $P_P : P_Q = 2:1$.

74. Power $= 1.5$ kW and everyday use = 2 h

Energy used everyday $= 1.5 \times 2 = 3$ kWh

Total energy used $= 3 \times 31$ kWh

(January = 31 days)

$= 93$ kWh

$= 93$ unit ($\because$ 1 kWh = 1 unit)

75. Heating elements like as : nichrome, manganin, etc., have large resistivity. Copper is a good conductor of electricity and it has low resistivity. So, it does not used as a heating element.

76. With the help of Wheatstone bridge we can determine the values of a known and unknown resistance.

77. Kirchhoff's junction rule states that, total incoming current is equal to total outgoing current at a node or junction. This implies at a certain time the net charge on a node stays constant, which is conservation of charge.

78. Net current at node = 0A

Hence, $4\text{A} + 3\text{A} - 1\text{A} + X = 0$

$$6\text{A} + X = 0$$

$$X = -6\text{A}$$

which means current in fourth wire is 6A, going out from the node.

79. A galvanometer is used as the null detector in a Wheatstone bridge.

The null point means the situation in which no current flows through the circuit.

80. According to balanced Wheatstone bridge equation,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$$\Rightarrow \quad \frac{500}{800} = \frac{X + 400}{1000}$$

$$X + 400 = \frac{500}{800} \times 1000$$

$$X + 400 = 0.625 \times 1000$$

$$X = 625 - 400$$

$$X = 225\,\Omega$$

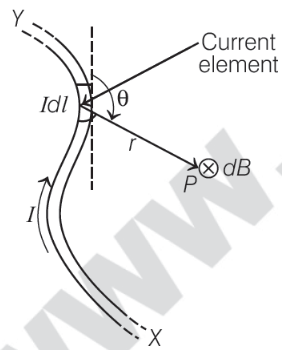
04

Moving Charges and Magnetism

Quick Revision

1. **Biot-Savart's Law** According to this law, the magnetic field due to small current carrying element at any nearby point P is given by

$$d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{Id\mathbf{l} \times \mathbf{r}}{r^3} \text{ or } dB = \frac{\mu_0}{4\pi}\frac{Id\,l \sin\theta}{r^2}$$



and direction is given by Ampere's swimming rule or right hand thumb rule.

The SI unit of magnetic field is tesla.

$$\frac{\mu_0}{4\pi} = 10^{-7} \text{ T-m / A} \quad \text{(or Wb/A-m)}$$

where, μ_0 = permeability of free space.

2. Magnetic field due to infinitely straight current carrying conductor at any point P lies near the middle of conductor at a distance r from the wire is given by $B = \frac{\mu_0}{4\pi}\frac{2I}{r} = \frac{\mu_0 I}{2\pi r}$

$$\Rightarrow \qquad B \propto \frac{1}{r}$$

3. Magnetic field at the centre of a circular current carrying conductor/coil, $B = \frac{\mu_0 I}{2r}$

For N-turns of coil, $B = \frac{\mu_0 NI}{2r}$

The direction of magnetic field at the centre of circular loop is given by right hand thumb rule.

4. **Ampere's Circuital Law** The line integral of the magnetic field **B** around any closed loop in vacuum is equal to μ_0 times the total current threading through the loop or enclosed by the curve. i.e. $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I$

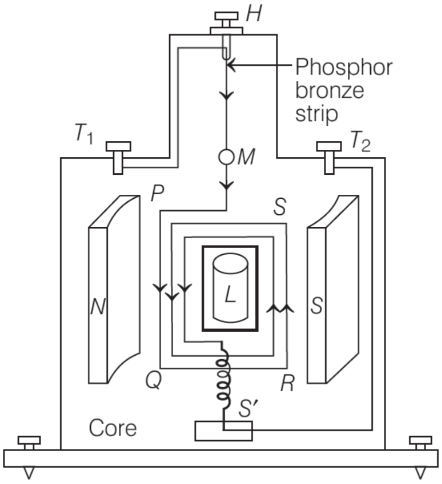
5. **Magnetic field due to straight solenoid** Magnetic field due to straight current carrying solenoid,
   - at any point inside the solenoid, $B = \mu_0 nI$ where, n = number of turns per unit length.
   - at the ends of air closed solenoid, $B = \frac{1}{2}\mu_0 nI$

6. **Magnetic field due to toroidal solenoid**

   If a toroid has core of relative permeability μ_r, then magnetic field
   - inside the toroidal solenoid,
   $$B = \mu_0 nI$$
   - in the open space, interior or exterior of toroidal solenoid,
   $$B = 0$$

7. **Magnetic force** experienced by a single charge particle q moving with speed v in uniform magnetic field at an angle θ with it, is given by
$$\mathbf{F} = q(\mathbf{v} \times \mathbf{B}) \quad \text{[vector form]}$$
Magnitude of force is $F = qvB \sin\theta$ and direction of force is given by right hand (palm) rule or Fleming's left hand rule.
8. Work done by magnetic Lorentz force on charge particle is zero as $\mathbf{F} \perp \mathbf{v}$.
9. Magnetic force cannot increase the kinetic energy of charged particle.
10. The trajectory/path traversed by the charged particle in magnetic field is
   - **straight line,** when angle between **v** and **B** is $0°$ or $180°$.
   - **circle,** when angle between **v** and **B** is $90°$.
   - **helical,** when angle between **v** and **B** is an acute angle.
11. When charged particle enters in magnetic field perpendicularly, then
$$f_{\text{centripetal}} = f_{\text{magnetic}}$$
   - Hence, $\frac{mv^2}{r} = qvB \Rightarrow v = \frac{qBr}{m}$
   - Radius, $r = \frac{mv}{qB}$
   - Time period, $T = \frac{1}{f} = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$ (independent of v)
   - Frequency, $f = \frac{qB}{2\pi m}$
   - KE $= \frac{q^2B^2r^2}{2m}$
12. When angle between **v** and **B** is $\theta < 90°$, then
   - radius of helical path, $r = \frac{mv\sin\theta}{qB}$
   - pitch $= \frac{2\pi m v \cos\theta}{qB} = v_{||} \times T$
13. If a charge particle q accelerated by potential difference V and speed changes from 0 to v, then
Work done = Change in KE
$$\Rightarrow \quad qV = \frac{1}{2}mv^2$$
$$\Rightarrow \quad v = \sqrt{\frac{2qV}{m}}$$
14. The magnetic force experienced by a current carrying conductor placed in a uniform magnetic field is given by
$$\mathbf{F} = I(\mathbf{l} \times \mathbf{B}) \quad \text{[vector form]}$$
where, **l** is a vector whose magnitude is equal to length of the conductor and direction is in the flow of electric current I and **B** is magnetic field.
$$F = IBl \sin\theta$$
where, θ is the angle between current and magnetic field.
   - If $\theta = 0°$ or $180°$, then $F = IBl \sin 0° = 0$
   So, conductors placed parallel to direction of magnetic field, experiences no force due to magnetic field.
   - If $\theta = 90°$, then force is maximum,
   $$F_{\max} = IBl \sin 90° = IBl$$
15. Magnetic force per unit length between two straight parallel current carrying conductors is given by
$$\frac{F}{L} = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$$
Force will be of attractive nature, if directions of flow of currents are in the same direction. However, force of repulsion will act, when direction of flow of currents are in opposite directions.
16. **Torque** experienced by a current carrying loop placed in uniform magnetic field B is given by
$$\tau = NIAB \sin\theta$$
where, θ is the angle between area vector of coil and the direction of magnetic field.
or $\quad \tau = \mathbf{M} \times \mathbf{B}$
where, $\quad \mathbf{M} = NI\mathbf{A}$
and **M** is known as **magnetic dipole moment** of coil.
17. **Moving Coil Galvanometer** is a device used to detect the small electrical current in the circuit. Its working is based on the principle

that a current carrying loop placed in uniform magnetic field experiences a torque.



18. The current sensitivity and voltage sensitivity of galvanometer depends on number of turns of coil, magnetic field B, area A of the coil and torsion constant k of the spring or suspension wire.
   - **Current sensitivity**,
   $$I_S = \frac{\theta}{I} = \frac{NBA}{k}$$
   where, θ = twist produced due to rotation of the coil.
   Its unit is rad/A or div/A.
   - **Voltage sensitivity**,
   $$V_S = \frac{\theta}{V} = \frac{\theta}{IR} = \frac{I_S}{R} = \frac{NBA}{kR}$$
   Its unit is rad/V or div/V.
19. In equilibrium position,
   deflecting torque = restoring torque
   $$NIBA = k\theta$$
   $$\Rightarrow \quad I = \frac{k}{NBA}\theta = G\theta$$
   $$G = \frac{k}{NBA}$$
20. A **galvanometer** can be converted into an **ammeter** by connecting a very low resistance (shunt S) in parallel with galvanometer, which is given by
   $$S = \frac{I_g G}{I - I_g}$$
   where,
   G = resistance of galvanometer,
   I_g = current through the galvanometer
   and I = total current in the circuit.
21. A **galvanometer** can be converted into **voltmeter** by connecting a very high resistance R in series with galvanometer which is given by
   $$R = \frac{V}{I_g} - G$$
   where,
   I_g = current through the galvanometer (full scale deflection current),
   G = resistance of galvanometer
   and V = potential difference across the terminals.
22. The resistance of an **ideal ammeter** is zero and an ideal voltmeter is infinite.
23. Ammeter is always connected in series with electrical circuit, whereas voltmeter connected in parallel with the circuit.

Objective Questions

Multiple Choice Questions

1. Biot-Savart's law may be represented in vector form as

(a) $d\mathbf{B} = \frac{\mu_0}{4\pi} I \frac{d\mathbf{l} \times \mathbf{r}}{r^3}$ (b) $d\mathbf{B} = \frac{\mu_0}{4\pi} I\, d\mathbf{l} \times \mathbf{r}$

(c) $d\mathbf{B} = \frac{\mu_0}{4\pi} I \frac{d\mathbf{l} \times \mathbf{r}}{r^2}$ (d) $d\mathbf{B} = \frac{\mu_0}{4\pi} I \frac{d\mathbf{l} \times \mathbf{r}}{r}$

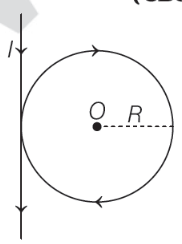
2. Biot-Savart law indicates that the moving electrons (velocity $\mathbf{v}$) produce a magnetic field $\mathbf{B}$ such that ***(NCERT Exemplar)***

(a) $\mathbf{B}$ is perpendicular to $\mathbf{v}$
(b) $\mathbf{B}$ is parallel to $\mathbf{v}$
(c) it obeys inverse cube law
(d) it is along the line joining the electron and point of observation

3. A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field B at the centre of the coil?

(a) $\pi \times 10^{-3}$ T (b) $2\pi \times 10^{-4}$ T
(c) $\pi \times 10^{-4}$ T (d) Zero

4. A current I flows through a long straight conductor which is bent into a circular loop of radius R in the middle as shown in the figure. ***(CBSE All India 2020)***



The magnitude of the net magnetic field at point O will be

(a) zero (b) $\frac{\mu_0 I}{2R}(1+\pi)$

(c) $\frac{\mu_0 I}{4\pi R}$ (d) $\frac{\mu_0 I}{2R}\left(1-\frac{1}{\pi}\right)$

5. A current of 10A is flowing from east to west in a long straight wire kept on a horizontal table. The magnetic field developed at a distance of 10 cm due north on the table is ***(CBSE All India 2020)***

(a) 2×10^{-5} T, acting downwards
(b) 2×10^{-5} T, acting upwards
(c) 4×10^{-5} T, acting downwards
(d) 4×10^{-5} T, acting upwards

6. Magnetic field due to a ring having n turns at a distance x on its axis is proportional to (if, r = radius of ring)

(a) $\frac{r}{(x^2 + r^2)}$

(b) $\frac{r}{(x^2 + r^2)^{3/2}}$

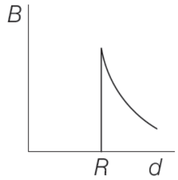
(c) $\frac{nr^2}{(x^2 + r^2)^{3/2}}$

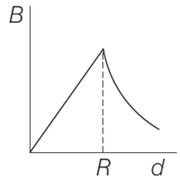
(d) $\frac{n^2 r^2}{(x^2 + r^2)^{3/2}}$

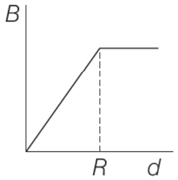
7. According to Ampere's circuital law, the line integral of the magnetic field around any closed loop is

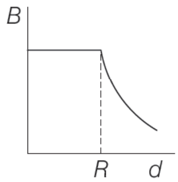
(a) equal to $\frac{1}{\mu_0}$ times the total current flowing through the loop
(b) equal to μ_0 times the total current flowing through the loop
(c) equal to $\frac{\mu_0}{\varepsilon_0}$ times the total current flowing through the loop
(d) equal to $\frac{\varepsilon_0}{\mu_0}$ times the total current flowing through the loop

8. A cylindrical conductor of radius R is carrying a constant current. The plot of the magnitude of the magnetic field B with the distance d from the centre of the conductor, is correctly represented by the figure

(a) 

(b) 

(c) 

(d) 

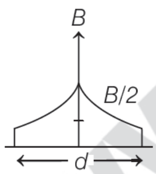
9. The magnitude of the magnetic field inside a long solenoid is increased by

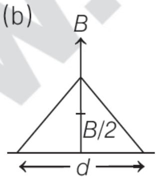
(a) decreasing its radius
(b) decreasing the current through it
(c) increasing its area of cross-section
(d) introducing a medium of higher permeability

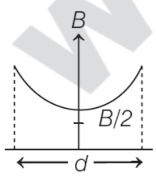
10. A long solenoid carrying a current produces a magnetic field B along its axis. If the current is doubled and the number of turns/cm is halved, the new value of the magnetic field is

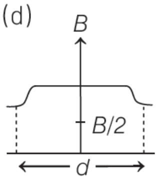
(a) $2B$ (b) $4B$ (c) $B/2$ (d) B

11. The variation of magnetic field with distance d from centre of current carrying solenoid is best represented by

(a) 

(b) 

(c) 

(d) 

12. Toroid is

(a) ring shaped closed solenoid
(b) rectangular shaped solenoid
(c) ring shaped open solenoid
(d) square shaped solenoid

13. A toroid having 200 turns carries a current of 1A. The average radius of the toroid is 10 cm. The magnetic field at any point in the open space inside the toroid is

(a) 4×10^{-3} T (b) zero
(c) 0.5×10^{-3} T (d) 3×10^{-3}T

14. Two toroids 1 and 2 have total number of turns 200 and 100 respectively with average radii 40 cm and 20 cm, respectively. If they carry same current i, the ratio of the magnetic fields along the two loops is

(a) 1 : 1 (b) 4 : 1
(c) 2 : 1 (d) 1 : 2

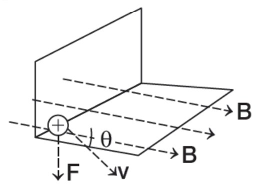
15. The current in the windings on a toroid is 2.0 A. There are 400 turns and the mean circumferential length is 40 cm. If the inside magnetic field is 1.0 T, the relative permeability is near about

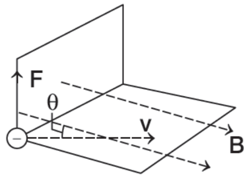
(a) 100 (b) 200
(c) 300 (d) 400

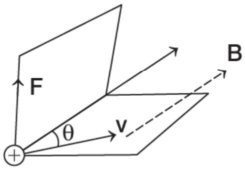
16. Time period of a charged particle undergoing a circular motion in a uniform magnetic field is independent of ***(CBSE SQP 2020)***

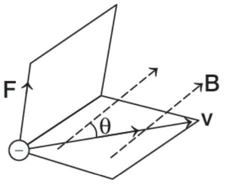
(a) speed of the particle
(b) mass of the particle
(c) charge of the particle
(d) magnetic field

17. Which of the following diagram is correct for the direction of magnetic force on a charge moving in a uniform magnetic field?

(a) 

(b) 

(c) 

(d) 

18. Two particles of masses m_a & m_b and same charge are projected in a perpendicular magnetic field. They travel along circular paths of radius r_a and r_b such that $r_a > r_b$. Then, which is true?

(a) $m_a v_a > m_b v_b$
(b) $m_a > m_b$ and $v_a > v_b$
(c) $m_a = m_b$ and $v_a > v_b$
(d) $m_b v_b > m_a v_a$

19. A charge particle after being accelerated through a potential difference V enters in a uniform magnetic field and moves in a circle of radius r. If V is doubled, the radius of the circle will become ***(CBSE Delhi 2020)***

(a) $2r$ (b) $\sqrt{2}\,r$ (c) $4r$ (d) $\dfrac{r}{\sqrt{2}}$

20. Two charged particles traverse identical helical paths in a completely opposite sense in a uniform magnetic field $\mathbf{B} = B_0\hat{\mathbf{k}}$. ***(NCERT Exemplar)***

(a) They have equal z-components of momenta
(b) They must have equal charges
(c) They necessarily represent a particle, anti-particle pair
(d) The charge to mass ratio satisfy $\left(\dfrac{e}{m}\right)_1 + \left(\dfrac{e}{m}\right)_2 = 0$

21. If the velocity of charged particle has both perpendicular and parallel components while moving through a magnetic field, what is the path followed by a charged particle?

(a) Circular (b) Elliptical
(c) Linear (d) Helical

22. A beam of protons with a velocity of $4 \times 10^5\ \text{ms}^{-1}$ moves in the direction of uniform magnetic field. It makes an angle of 37° with the magnetic field and follows a helical path. If the time period of helix is 2×10^{-7} s, then its pitch will be

(a) 2 cm (b) 4 cm (c) 8 cm (d) 6 cm

23. Lorentz force can be correctly expressed by the relation

(a) $\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$ (b) $\mathbf{F} = q(\mathbf{E} - \mathbf{v} \times \mathbf{B})$
(c) $\mathbf{F} = q(\mathbf{E} + \mathbf{v} \cdot \mathbf{B})$ (d) $\mathbf{F} = q(\mathbf{E} \times \mathbf{v} + \mathbf{B})$

24. A proton beam passes without deviation through a region of space. This space has uniform transverse mutually perpendicular electric and magnetic fields with $E = 220$ kV / m and $B = 50$ mT. The velocity of the beam is

(a) 4.4×10^6 m/s (b) 2.2×10^6 m/s
(c) 4×10^6 m/s (d) 2×10^6 m/s

25. When a current carrying conductor of length l is placed parallel to the magnetic field, the magnitude of force due to current carrying conductor is equal to

(a) zero (b) IlB (c) $\dfrac{IlB}{2}$ (d) $-IlB$

26. Two parallel wires carrying currents in the same direction attract each other because of

(a) potential difference between them
(b) mutual inductance between them
(c) electric force between them
(d) magnetic force between them

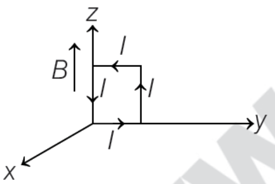
27. Two long conductors, separated by a distance d carry currents I_1 and I_2 in the same direction. They exert a force F on each other. Now, the current in one of them is increased to two times and its direction is reversed. The distance is also increased to $3d$. The new value of the force between them is

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

28. A current carrying square loop is suspended in a uniform magnetic field acting in the plane of the loop. If the force on one arm of the loop is **F**, then the net force on the remaining three arms of the loop is

(a) 3**F** (b) –**F**
(c) –3**F** (d) **F**

29. A rectangular loop of sides 10 cm and 5 cm carrying a current I of 12 A is placed in different orientations as shown in the figures.

I.


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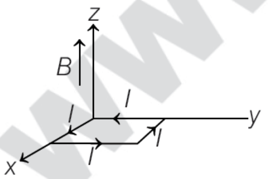
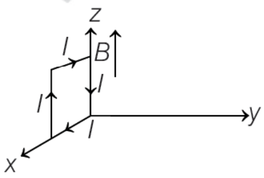
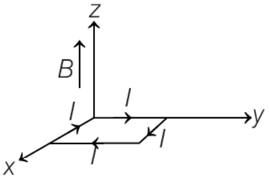


III.


IV.


If there is a uniform magnetic field of 0.3 T in the positive z-direction, in which orientations the loop would be in (i) stable equilibrium and (ii) unstable equilibrium?

(a) I and II (b) I and III
(c) II and IV (d) II and III

30. The full scale deflection current of a galvanometer of resistance $1\,\Omega$ is 5 mA. What is the value of resistance R, which is connected in series to convert it into a voltmeter of range 5 V?

(a) $99\,\Omega$ (b) $999\,\Omega$
(c) $1000\,\Omega$ (d) $100\,\Omega$

31. Two galvanometers A and B require 3 mA and 5 mA respectively to produce the same deflection of I_0 division. Then,

(a) A is more sensitive than B
(b) B is more sensitive than A
(c) A and B are equally sensitive
(d) sensitiveness of B is 5/3 times of that of A

32. A galvanometer acting as a voltmeter should have

(a) low resistance in series with its coil
(b) low resistance in parallel with its coil
(c) high resistance in series with its coil
(d) high resistance in parallel with its coil

33. A galvanometer has a resistance of $100\,\Omega$. A potential difference of 100 mV between its terminals gives a full scale deflection. The shunt resistance required to convert it into an ammeter reading upto 5 A is

(a) $0.01\,\Omega$ (b) $0.02\,\Omega$
(c) $0.03\,\Omega$ (d) $0.04\,\Omega$

34. Magnetic field in a region is produced only by ....

(a) static charges
(b) moving charges
(c) oscillatory charges
(d) Both (b) and (c)

35. A charged particle enters a magnetic field B with its initial velocity making an angle of 45° with B. The path of the particle will be ....

(a) straight line (b) a circle
(c) an ellipse (d) a helix

36. A small circular flexible loop of wire of radius r carries a current I. It is placed in a uniform magnetic field B. The tension in the loop will be doubled, if .... is doubled.

(a) I (b) B
(c) r (d) both B and I

37. Equal current is being passed through two very long and straight parallel wires in the same direction. They will .... each other.

(a) attract
(b) repel
(c) Both (a) and (b)
(d) None of the above

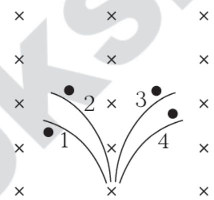
38. Which of the following statement is correct regarding the Coulomb's force and Biot-Savart's force?

(a) Electrostatic force is along the displacement vector joining the source and the field but magnetic force is perpendicular to the plane containing the displacement vector and source.
(b) There is an angle dependence in the Biot-Savart's law, which is present in Coulomb's law.
(c) Biot-Savart's law can be expressed in vector form but Coulomb's law cannot be expressed in vector form.
(d) Biot-Savart's law is applicable in all medium but Coulomb's law is applicable only in medium which can be polarised.

39. Which of the following statement(s) is/are incorrect?

(a) In a solenoid, the net magnetic field is the vector sum of the fields due to all the turns.
(b) Enamelled wires are used for winding, so that turns are insulated from each other.
(c) The field inside the solenoid approaches zero and everywhere outside becomes parallel to the axis.
(d) The solenoid is commonly used to obtain a uniform magnetic field.

40. Four particles α-particle, deuteron, electron and a Cl^- ion enter in a transverse magnetic field perpendicular to it with same kinetic energy. Their paths are as shown in figure. Now, match the following two columns.



	Column I		Column II
A.	Deuteron	p.	Path-1
B.	α-particle	q.	Path-2
C.	Electron	r.	Path-3
D.	Cl^-	s.	Path-4

Codes

	A	B	C	D
(a)	p	q	s	r
(b)	q	p	r	s
(c)	p	q	r	s
(d)	q	s	p	r

41. A charged particle with some initial velocity is projected in a region where non-zero electric and/or magnetic field(s) are present.

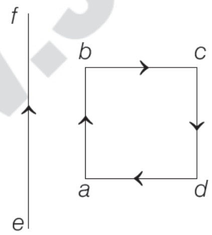
In **Column I**, information about the existence of electric and/or magnetic field(s) and direction of initial velocity of charged particle are given, while in **Column II** the probable path of the charged particle is mentioned. Match the entries of Column I with the entries of Column II and select the correct answer from the codes given below.

	Column I		Column II
A.	$\mathbf{E}=0$, $\mathbf{B}\neq 0$, $\mathbf{E}\neq\mathbf{B}$ and initial velocity is at any angle with $\mathbf{B}$ $(\theta\neq 90^\circ)$.	p.	Straight line
B.	$\mathbf{E}=0$, $\mathbf{B}\neq 0$ and initial velocity is perpendicular to $\mathbf{B}$.	q.	Helical path with uniform pitch
C.	$\mathbf{E}\neq 0$, $\mathbf{B}\neq 0$, $\mathbf{E}\,\|\,\mathbf{B}$ and initial velocity is perpendicular to both.	r.	Circular
D.	$\mathbf{E}\neq 0$, $\mathbf{B}\neq 0$, $\mathbf{E}$ perpendicular to $\mathbf{B}$ and $\mathbf{v}$ perpendicular to both $\mathbf{E}$ and $\mathbf{B}$.	s.	Helical path with non-uniform pitch

Codes

	A	B	C	D		A	B	C	D
(a)	q	r	s	p	(b)	p	r	s	q
(c)	q	r	p	s	(d)	s	p	q	r

42. A square current carrying loop *abcd* is placed near an infinitely long another current carrying wire *ef*.



Now, match the following two columns.

	Column I		Column II
A.	Net force on *bc* and *da*	p.	zero
B.	Net force on *ab* and *cd*	q.	non-zero
C.	Net force on complete loop *abcd*	r.	rightwards
D.	Net force on *ab*	s.	constant

Codes

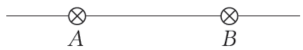
	A	B	C	D		A	B	C	D
(a)	q	p	q	q	(b)	p	q	q	q
(c)	p	q	r	p	(d)	p	q	q	q

Assertion/Reasoning MCQs

*For question numbers 43 to 56, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

43. Assertion Two infinitely long wires *A* and *B* carry unequal currents in inward direction.



Then, there is only one point (excluding the points at infinity), where net magnetic field is zero.

Reason That point lies between points *A* and *B*.

44. Assertion The magnetic field produced by a current carrying solenoid is independent of its length and cross-sectional area.

Reason The magnetic field inside the solenoid is uniform.

45. Assertion A magnetic field interacts with a moving charge and not with a stationary charge.

Reason A moving charge produce a magnetic field.

46. **Assertion** Electron moving perpendicular to **B** will perform circular motion.

Reason Force by magnetic field is perpendicular to velocity.

47. **Assertion** A charge particle is released from rest in magnetic field, then it will move in a circular path.

Reason Work done by magnetic field is non-zero.

48. **Assertion** If a moving charged particle enters into a region of magnetic field from outside, it does not complete a circular path.

Reason Power associated with the force exerted by a magnetic field on a moving charged particle is always equal to unity.

49. **Assertion** If a charged particle is projected in a region, where **B** is perpendicular to velocity of projection, then the net force acting on the particle is independent of its mass.

Reason The particle is performing uniform circular motion and force acting on it is $\frac{mv^2}{r}$.

50. **Assertion** When a charged particle moves in a region of magnetic field such that its velocity is at some acute angle with the direction of field, its trajectory is a helix.

Reason Perpendicular component of velocity causes a rotating centripetal force and parallel component of velocity does not produces any force.

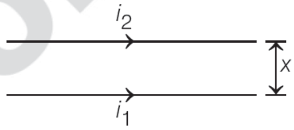
51. **Assertion** A beam of electron can pass undeflected through a region of **E** and **B**.

Reason Force on moving charged particle due to magnetic field may be zero in some cases.

52. **Assertion** If the path of a charged particle in a region of uniform electric and magnetic field is not a circle, then its kinetic energy may remain constant.

Reason In a combined electric and magnetic fields region, a moving charge experiences a net force $\mathbf{F} = q\,\mathbf{E} + q\,(\mathbf{v} \times \mathbf{B})$, where symbols have their usual meanings.

53. **Assertion** Upper wire shown in figure is fixed. At a certain distance x, lower wire can remain in equilibrium.



Reason The above equilibrium of lower wire is stable equilibrium.

54. **Assertion** For a current carrying wire loop of N turns, placed in a region of a uniform magnetic field B, the torque acting on it is given by $\mathrm{m} \times \mathrm{B}$.

Reason Whenever the magnetic moment m is perpendicular to B, then torque on the loop will be zero.

55. **Assertion** The current sensitivity of a galvanometer is the deflection of current per unit current passing through the coil.

Reason The galvanometer can be used as a detector to check, if a current is flowing in the circuit.

56. **Assertion** If we increase the current sensitivity of a galvanometer by increasing number of turns, its voltage sensitivity also increases.

Reason Resistance of a wire also increases with N.

Case Based MCQs

Direction *Answer the questions from 57-61 on the following case.*

Electron Moving in Magnetic Field

An electron with a speed $v_0 (<< c)$ moves in a circle of radius r_0, in a uniform magnetic field. This electron is able to travel in a circular path as magnetic field is perpendicular to the velocity of the electron. The time required for one revolution of the electron is T_0. The speed of the electron is now, doubled to $2v_0$.

57. The radius of the circle will change to

(a) $4r_0$ (b) $2r_0$ (c) r_0 (d) $r_0/2$

58. The time required for one revolution of the electron will change to

(a) $4T_0$ (b) $2T_0$ (c) T_0 (d) $T_0/2$

59. A charged particle is projected in a magnetic field $\mathbf{B} = (2\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) \times 10^2$ T. The acceleration of the particle is found to be $\mathbf{a} = (x\hat{\mathbf{i}} + 2\hat{\mathbf{j}})\text{ms}^{-2}$. Find the value of x.

(a) 4 (b) −4
(c) −2 (d) 2

60. If the given electron has a velocity not perpendicular to **B**, then the trajectory of the electron is

(a) straight line (b) circular
(c) helical (d) *zig-zag*

61. If this electron of charge (e) is moving parallel to uniform magnetic field with constant velocity v. The force acting on the electron is

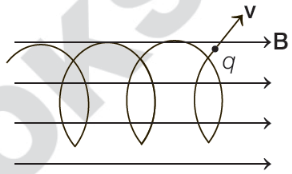
(a) Bev (b) $\frac{Be}{v}$ (c) $\frac{B}{ev}$ (d) zero

Direction *Answer the questions from 62-66 on the following case.*

Lorentz Force and Its Effects

A charged particle moving in an external magnetic field experiences a force, which is called Lorentz force, i.e. $\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$, where q is the charge on the particle and v is the velocity of the particle. The direction of the force is given by the cross product of velocity vector and magnetic field vector at any time.

The charge particle travels in a special trajectory called helical path. Because the force is always perpendicular to the velocity vector, the magnetic field can do no work on an isolate charge. Hence, the linear velocity always remains the same.



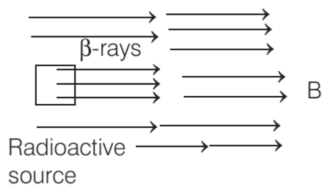
62. The force experienced on a stationary charged particle in a magnetic field is

(a) maximum
(b) constant but greater than zero
(c) zero
(d) variable but greater than zero

63. A proton enters in solenoid with uniform velocity v along the axis of the solenoid, then

(a) velocity increases
(b) proton is repelled backwards
(c) proton moves along a helical path
(d) force experienced by the proton is zero

64. An radioactive nuclei emits β-rays. In a uniform magnetic field shown in the figure, the β-rays



(a) will get deflected upwards
(b) will not get deflected
(c) will get deflected downwards
(d) will get deflected out of the plane of the paper

65. A dipole is thrown into a uniform magnetic field with non-zero kinetic energy. The dipole will
(a) start rotating
(b) move in rectilinear motion
(c) execute SHM
(d) rotate and move along with magnetic field

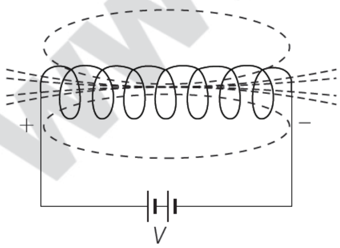
66. The force on a charged particle moving with a velocity v in a magnetic field B is not
(a) perpendicular to both v and B
(b) maximum, if v is perpendicular to B
(c) maximum, if v is parallel to B
(d) zero, if v is parallel to B

Direction *Answer the questions from 67-71 on the following case.*

Magnetic Field of a Solenoid

Mohan tightly wound a very long copper wire on a PVC pipe and carefully took the pipe out. The two ends of the copper wire then attached to a battery.

This cylindrical shape of copper wire showed few properties of a bar magnet. Later he found that it is called a solenoid and this solenoid is used in several devices such as door bell, relay switch etc. The magnetic field of a solenoid is given below



The magnetic field strength of a solenoid having n turns is $B = \mu_0 nI$, where, I is the current flowing in the solenoid.

67. A long solenoid having 400 turns is used as electromagnet. If 1.5 A current is flowing through the solenoid, the strength of the electromagnet is
(a) 0.2 mT (b) 0.4 mT
(c) 0.6 mT (d) 0.8 mT

68. An electromagnet is made up by introducing a soft iron core having magnetic permeability μ_r in the solenoid. The magnetic field strength of solenoid becomes
(a) $\mu_0 I$ (b) $\mu_0 n I^2$
(c) $\mu_0 \mu_r n I$ (d) None of these

69. The strength of magnetic field in a solenoid cannot be increased by
(a) decreasing its length
(b) increase the value of current
(c) introduce a magnetic and material inside the coil
(d) increase the number of turns

70. The magnetic field outside a solenoid is
(a) infinity
(b) zero
(c) double the value of field inside
(d) half the value of the field inside

71. The nature of magnetic field lines passing through the centre of current carrying solenoid is
(a) circular (b) ellipse
(c) parabolic (d) straight line

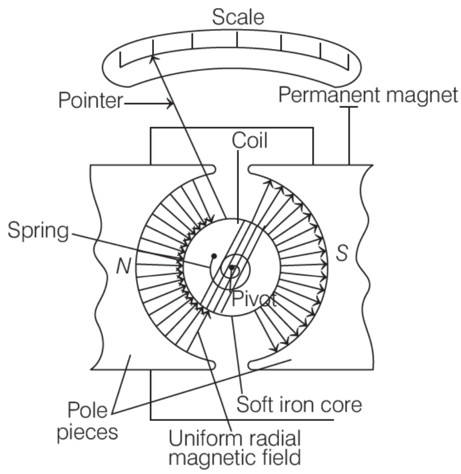
Direction *Answer the questions from 72-76 on the following case.*

Moving Coil Galvanometer

Moving coil galvanometer operates on Permanent Magnet Moving Coil (PMMC) mechanism and was designed by the scientist D'arsonval.

Moving coil galvanometers are of two types
(i) Suspended coil
(ii) Pivoted coil type or tangent galvanometer.

Its working is based on the fact that when a current carrying coil is placed in a magnetic field, it experiences a torque. This torque tends to rotate the coil about its axis of suspension in such a way that the magnetic flux passing through the coil is maximum.



72. A moving coil galvanometer is an instrument, which

(a) is used to measure emf of cell
(b) is used to measure potential difference
(c) is used to measure resistance
(d) is a deflection type instrument that gives a deflection when a current flows through its coil

73. To make the field radial in a moving coil galvanometer,

(a) number of turns of coil is kept small
(b) magnet is taken in the form of horse-shoe
(c) poles are of very strong magnets
(d) poles are cylindrically cut

74. The deflection in a moving coil galvanometer is

(a) directly proportional to torsional constant of spring
(b) directly proportional to the number of turns in the coil
(c) inversely proportional to the area of the coil
(d) inversely proportional to the current in the coil

75. In a moving coil galvanometer, having a coil of N-turns of area A and carrying current I is placed in a radial field of strength B.

The torque acting on the coil is

(a) NA^2B^2I (b) $NABI^2$ (c) N^2ABI (d) $NABI$

76. To increase the current sensitivity of a moving coil galvanometer, we should decrease

(a) strength of magnet
(b) torsional constant of spring
(c) number of turns in coil
(d) area of coil

ANSWERS

Multiple Choice Questions

1. (a)	2. (a)	3. (c)	4. (d)	5. (a)	6. (c)	7. (b)	8. (b)	9. (d)	10. (d)
11. (d)	12. (a)	13. (b)	14. (a)	15. (d)	16. (a)	17. (c)	18. (a)	19. (b)	20. (d)
21. (d)	22. (c)	23. (a)	24. (a)	25. (a)	26. (d)	27. (d)	28. (b)	29. (c)	30. (b)
31. (a)	32. (c)	33. (b)	34. (d)	35. (d)	36. (a)	37. (a)	38. (a)	39. (c)	40. (a)
41. (a)	42. (d)								

Assertion/Reasoning MCQs

43. (b)	44. (b)	45. (a)	46. (a)	47. (d)	48. (c)	49. (c)	50. (a)	51. (b)	52. (b)
53. (c)	54. (c)	55. (b)	56. (c)						

Case Based MCQs

57. (b)	58. (c)	59. (b)	60. (c)	61. (d)	62. (c)	63. (c)	64. (b)	65. (d)	66. (c)
67. (d)	68. (c)	69. (a)	70. (b)	71. (d)	72. (d)	73. (d)	74. (b)	75. (d)	76. (b)

SOLUTIONS

1. Biot-Savart's law in vector form is given as

$$d\,\mathbf{B} = \frac{\mu_0}{4\pi} I \frac{d\mathbf{l} \times \mathbf{r}}{r^3}$$

2. In Biot-Savart's law, the direction of $d\mathbf{B}$ would be the direction of cross-product vector $(d\mathbf{l} \times \mathbf{r})$ which is represented by the right hand screw rule. Here, $d\mathbf{B}$ is perpendicular to the plane containing, $d\mathbf{l}$ and $\mathbf{r}$ is directed inwards.

As, $\mathbf{B} \perp \mathbf{v}$, electrons flow in perpendicular direction of magnetic field.

3. Given, $N = 100$, $r = 8$ cm $= 0.08$ m, $I = 0.4$A, $B = ?$

$$B = \frac{\mu_0 NI}{2r} = \frac{4\pi \times 10^{-7} \times 100 \times 0.4}{2 \times 0.08}$$
$$= \pi \times 10^{-4}\ \text{T}$$

4. The magnetic field due to the long straight conductor at point O is given by

$$B_1 = \frac{\mu_0 I}{2\pi R} \otimes$$

and that due to circular loop of radius R is

$$B_2 = \frac{\mu_0 I}{2R}$$

As, $\quad B_2 > B_1$

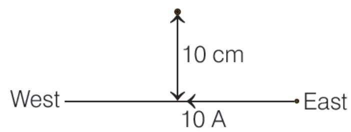
$\therefore$ The magnitude of net magnetic field at point O is

$$B_{\text{net}} = B_2 - B_1 = \frac{\mu_0 I}{2R} - \frac{\mu_0 I}{2\pi R}$$
$$= \frac{\mu_0 I}{2R}\left(1 - \frac{1}{\pi}\right)$$

5. Given, current, $I = 10$ A (East to West)

Distance, $r = 10\text{cm} = 10 \times 10^{-2}\,\text{m}$

Magnetic field, $|\mathbf{B}| = ?$



The magnitude of magnetic field $|\mathbf{B}|$ for infinite length of wire $= \dfrac{\mu_0 I}{2\pi r}$

$$\Rightarrow |\mathbf{B}| = \frac{4\pi \times 10^{-7} \times 10}{2 \times \pi \times 10 \times 10^{-2}} = 2 \times 10^{-5}\,\text{T}$$

(downwards)

The direction of magnetic field is given by right hand thumb rule or Maxwell's cork screw rule. So, the direction of magnetic field at point 10 cm North due to flowing current is perpendicularly inwards to the plane of paper.

6. Magnetic field due to a ring having n turns at a distance x on its axis is given by

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi n i r^2}{(x^2 + r^2)^{3/2}}$$

$$\therefore \quad B \propto \frac{nr^2}{(x^2 + r^2)^{3/2}}$$

7. According to Ampere's circuital law,

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enclosed}}$$

where, I_{enclosed} is the net current I flowing through the area enclosed by the closed path.

8. (i) The magnetic field at a point outside cylinder, i.e. $d > R$.

$$B = \frac{\mu_0 I}{2\pi d}$$

where, μ_0 = permeability of free space.

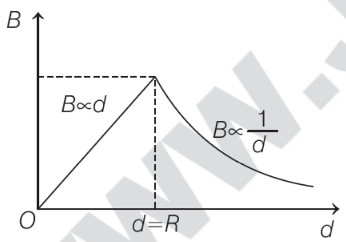
(ii) The magnetic field at a surface, i.e. $d = R$.

$$B = \frac{\mu_0 I}{2\pi R}$$

(iii) The magnetic field at inside point

$$\therefore \quad B = \frac{\mu_0 I}{2\pi R^2} d$$

So, the variation of magnetic field can be plotted as



9. Field along the axis of a solenoid is

$$B = \mu_0 n i$$

where, B = magnetic field,

μ_0 = permeability of free space,

n = the number of turns per unit length

and i = current.

So, according to the formula, magnitude of the magnetic field inside a long solenoid is increased by introducing a medium of higher permeability.

10. Magnetic field due to solenoid is given as

$$B = \mu_0 nI \quad \text{or} \quad B \propto nI$$

$$\therefore \quad \frac{B_1}{B_2} = \frac{n_1 I_1}{n_2 I_2} \qquad \ldots\text{(i)}$$

Here, $n_1 = n, n_2 = \frac{n}{2}, I_1 = I, I_2 = 2I, B_1 = B$

Putting these value in Eq. (i), we get

$$\frac{B}{B_2} = \frac{n}{n/2} \times \frac{I}{2I} = 1$$

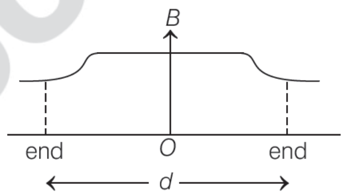
or $\quad B_2 = B$

11. Magnetic field inside the solenoid,

$$B = \mu_0 nI$$

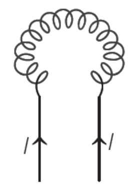
where, n = number of turns per unit length and I = current. Now, magnetic field outside the solenoid, $B = \frac{\mu_0 nI}{2}$.

$\therefore$ The variation of B is given by



12. Toroid is an endless solenoid in the form of a ring.

Magnetic field lines inside the toroid are circular concentric with centre of toroid.



13. Magnetic field **B** at any point in the open space inside the toroid is zero, because the amperian loop enclose net current equals to zero.

14. The magnetic field within the turns of toroid is

$$B = \frac{\mu_0 NI}{2\pi r}$$

where, N = number of turns, I = current in loops and r = radius of each turn.

Given, $N_1 = 200, N_2 = 100, r_1 = 40$ cm,

$r_2 = 20$ cm

and $\quad I = i$ (for both)

$$\therefore \quad \frac{B_1}{B_2} = \frac{\mu_0 N_1 I}{2\pi r_1} \times \frac{2\pi r_2}{\mu_0 N_2 I}$$

Substituting the given values in the above relation, we get

$$\frac{B_1}{B_2} = \left(\frac{N_1}{N_2}\right)\left(\frac{r_2}{r_1}\right)$$

$$= \left(\frac{200}{100}\right)\left(\frac{20}{40}\right) = 2 \times \frac{1}{2} = 1$$

$\therefore \; B_1 : B_2 = 1 : 1$

15. Magnetic field, $B = \dfrac{\mu_0 \mu_r N i}{2\pi r}$

$$1 = \frac{4\pi \times 10^{-7} \times \mu_r \times 400 \times 2}{40 \times 10^{-2}} \quad (\because 2\pi r = l)$$

$\therefore \quad \mu_r = 400$

16. Time period of revolution of charged particle in magnetic field, $T = \dfrac{2\pi m}{qB}$.

$$\therefore \quad T \propto m, \; T \propto \frac{1}{q} \text{ and } T \propto \frac{1}{B}$$

Hence, time period of a charged particle undergoing a circular motion in a uniform magnetic field is independent of velocity.

17. Direction of force on a moving charge in magnetic field can be found by right hand-rule.

As we know, the direction of **F** is the direction of cross product of velocity **v** and magnetic field **B**, which is perpendicular to the plane containing **v** and **B**.

So, for positive charge it acts upward and for negative charge it acts downward, hence diagram (c) is correct.

18. Radius of circular path,

$$r_a = \frac{m_a v_a}{qB} \text{ and } r_b = \frac{m_b v_b}{qB}$$

According to question, $r_a > r_b$

$$\therefore \quad \frac{m_a v_a}{qB} > \frac{m_b v_b}{qB}$$

or $\quad m_a v_a > m_b v_b$

19. For the given charged particle, the radius of the circular path is

$$r = \frac{mv}{Bq} = \frac{\sqrt{2q\,Vm}}{Bq} \qquad \ldots \text{(i)}$$

Keeping q, B and m fixed, if V is doubled, then

$$r' = \frac{\sqrt{2q(2V)m}}{Bq} = \frac{\sqrt{2}\sqrt{2q\,Vm}}{Bq}$$

$$= \sqrt{2}\, r \qquad \text{[from Eq. (i)]}$$

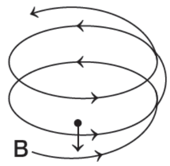
20. For given pitch P correspond to charge particle, we have

$$\frac{q}{m} = \frac{2\pi v \cos\theta}{qB} = \text{constant}$$

Since, charged particles traverse identical helical paths in a completely opposite sense in a uniform magnetic field **B**, LHS for two particles should be same and of opposite sign. Therefore, $\left(\dfrac{e}{m}\right)_1 + \left(\dfrac{e}{m}\right)_2 = 0$

Note Consider e in place of q in solution.

21. Suppose, the velocity **v** of the particle entering the magnetic field **B** makes some angle with **B**.



Then, **v** may be resolved into two components, $\mathbf{v}_{||} = v\cos\theta$ parallel to **B** and $\mathbf{v}_{\perp} = v\sin\theta$ perpendicular to **B**.

The component $\mathbf{v}_{||}$ gives a linear path and the component $\mathbf{v}_{\perp}$ gives a circular path to the particle. The resultant of these two is a helical path whose axis is parallel to the magnetic field.

22. Velocity of protons in the direction of B,

$$\mathbf{v}_{||} = 4 \times 10^5 \text{ ms}^{-1}$$

Time period of helix $= 2 \times 10^{-7}$ s

$$\text{Pitch} = \mathbf{v}_{||} \times T = 4 \times 10^5 \times 2 \times 10^{-7} = 0.08 \text{ m}$$

$$= 8 \text{ cm}$$

23. Lorentz force, $\mathbf{F}_{\text{net}} = \mathbf{F}_e + \mathbf{F}_m = q\mathbf{E} + q(\mathbf{v} \times \mathbf{B})$

$$= q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

24. Given, $E = 220 \text{ kV/m} = 220 \times 10^3 \text{ V/m}$

$$B = 50 \text{ mT} = 50 \times 10^{-3} \text{ T}$$

Since, proton is moving in a straight line, hence net force is zero.

$$qE = qvB \Rightarrow v = \frac{E}{B}$$

$$v = \frac{220 \times 10^3}{50 \times 10^{-3}}$$

$$\Rightarrow \quad v = 4.4 \times 10^6 \text{ m/s}$$

25. Force on a current carrying conductor when placed on a uniform magnetic field is

$$F = I(\mathbf{l} \times \mathbf{B}) \Rightarrow F = IlB \sin\theta$$

where, I = current flowing in the conductor,

l = length of the conductor

and B = uniform magnetic field.

If conductor is parallel to the magnetic field, then $\theta = 0°$.

$$\Rightarrow \quad F = IlB \sin 0° = 0$$

Hence, force will be zero.

26. Two parallel wires carrying currents in the same direction attract each other because magnetic force on the two wires act towards each other.

27. Force between two conductors, $F \propto \frac{I_1 I_2}{d}$

When I_1 is changed to $2I_1$ and d is changed to $3d$.

$$\therefore \quad F' \propto \frac{(2I_1)(I_2)}{3d} \propto \frac{2}{3}F$$

As, direction of current is reversed, so

$$F' = -2F/3$$

28. When a current carrying square loop is suspended in a uniform magnetic field, $\mathbf{F}_{net} = 0$, only torque acts on it. So, if force on one arm of the loop is $\mathbf{F}$, then force of remaining three arms of the loop must be $-\mathbf{F}$.

29. Since, $\mathbf{B}$ is uniform, then only torque acts on current carrying conductor.

As, we know that, torque, $\tau = \mathbf{m} \times \mathbf{B}$

$$\Rightarrow \quad |\tau| = |m||B| \sin\theta$$

where, m = magnetic moment of coil.

For given orientation (anti-clockwise) shown in II, $\theta = 0° \Rightarrow \tau = 0$

So, for this orientation the loop would be in stable equilibrium.

And for orientation (IV),

$$\theta = \pi \Rightarrow \tau = 0$$

Therefore, for this orientation (clockwise) the loop would be in unstable equilibrium.

30. From the relation, $V = I_g(G + R)$, we have

$$R = \frac{V}{I_g} - G = \left(\frac{5}{5 \times 10^{-3}}\right) - 1$$

$$= 999\ \Omega$$

i.e. A resistance of 999 Ω should be connected in series with the galvanometer to convert it into a voltmeter of desired range.

31. Sensitivity, $S = \frac{\theta}{i}$

$$\frac{S_A}{S_B} = \frac{i_B}{i_A} \Rightarrow \frac{S_A}{S_B} = \frac{5}{3} \Rightarrow S_A > S_B$$

Hence, sensitivity of A is more than B.

32. Galvanometer act as a voltmeter when a very high resistance is connected in series with its coil.

33. The current required for full scale deflection is

$$i_g = \frac{\text{PD across galvanometer}}{\text{resistance of galvanometer}}$$

$$= \frac{100 \times 10^{-3}}{100} = 10^{-3}\text{A}$$

The shunt resistance required is

$$S = \left(\frac{i_g}{i - i_g}\right)G = \left(\frac{10^{-3}}{5 - 10^{-3}}\right) \times 100$$

$$= 0.02\ \Omega$$

34. Static charges produce only electric field, whereas moving or oscillatory charges produce electric and magnetic fields both.

35. The component of velocity perpendicular to B will follow circular motion on the other hand, the component parallel to B will move along a straight line. The resultant of two components will make the motion helical.

36. When a circular flexible loop is placed in a magnetic field, a deflection torque (τ) acts on it, this is given by $\tau = MB \sin\theta$

where, M is dipole moment, B is magnetic field, θ is angle between magnetic field and axis of loop.

Also, $M = IA$, when I is doubled, the torque is doubled, hence tension is doubled.

37. Two infinitely long equal wire carrying equal currents in same direction will attract each other.

38. Statement (a) is correct but (b), (c) and (d) are incorrect and these can be corrected as,

There is an angle dependence in the Biot-Savart's law, which is not present in the electrostatic case.

Biot-Savart's law and Coulomb's law both can be expressed in vector form.

Biot-Savart's law and Coulomb's law, both are applicable in all type of medium.

39. Statement (c) is incorrect and it can be corrected as,

The field outside the solenoid approaches zero and everywhere inside becomes parallel to the axis. Rest statements are correct.

40. As, $r = \dfrac{\sqrt{2Km}}{Bq} \Rightarrow r \propto \dfrac{\sqrt{m}}{q}$

So, the particles having less charge has more radius of curvature.

Deuteron has charge $+e$ and will deviate more (part-1) α-particle has charge $+2e$ and will deviate less (path-2) electron has less charge as compared to Cl^-. Due to this, electron will deviate more than Cl^-.

Hence, A $\rightarrow$ p, B $\rightarrow$ q, C $\rightarrow$ s and D $\rightarrow$ r.

41. A. Since, $\mathbf{E} = 0$ and $\mathbf{B} \neq 0$ and $\mathbf{E} \neq \mathbf{B}$, the magnetic force act on it and the path will be helical (with uniform pitch) if $\mathbf{v}$ is at any angle to $\mathbf{B}$ $(\theta \neq 90°)$.

B. Since, $\mathbf{E} = 0$, $\mathbf{B} \neq 0$ and $\mathbf{v} \perp \mathbf{B}$, then a force called Lorentz force, $\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$, acts on charged particle, which provide centripetal force to it and hence the path will be circular.

C. Since, $\mathbf{E} \neq 0$, $\mathbf{B} \neq 0$, $\mathbf{E} \,||\, \mathbf{B}$, so path will be helical with non-uniform pitch as both electric and magnetic forces act on it.

D. Since, $\mathbf{E} \neq 0$, $\mathbf{B} \neq 0$, $\mathbf{E} \perp \mathbf{B}$ and $\mathbf{v}$ is perpendicular to both $\mathbf{E}$ and $\mathbf{B}$, then the particle will move in a straight line due to the resultant force of magnetic and electric fields.

Hence, A $\rightarrow$ q, B $\rightarrow$ r, C $\rightarrow$ s and D $\rightarrow$ p.

42. Magnetic field over the loop from the straight wire is perpendicular to paper inwards.

The direction of force in side *bc* and *ad* are opposite (using Fleming's left hand rule). Here, net force will be zero. But on sides *ab* and *cd*, net force will be non-zero. Also, net force on complete loop will be non-zero.

Hence, A $\rightarrow$ p, B $\rightarrow$ q, C $\rightarrow$ q and D $\rightarrow$ q.

43. To the right of *B*, both fields are downwards and to the left of *A* both fields are upwards.

Therefore, both A and R are true but R is not the correct explanation of A.

44. The magnetic field due to solenoid having n number of turns/m and carrying current I is $B = \mu_0 nI$.

It is obvious that magnetic field is independent of length and cross-sectional area. Also, magnetic field is uniform inside the solenoid.

Therefore, both A and R are true but R is not the correct explanation of A.

45. A stationary charge produces electric field only. However, a moving charge which is equivalent to a current is produce a magnetic field in the surrounding space and can interacts with external magnetic field.

Therefore, both A and R are true and R is the correct explanation of A.

46. When an electron enters in a direction perpendicular to the magnetic field, then a magnetic force acts on the electron which is given by $\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$ and direction of force can be determine by Fleming's left hand rule.

We know that, when a particle moves perpendicular with the direction of magnetic field, then it will make a uniform circular motion.

Therefore, electron moving perpendicular to magnetic field $\mathbf{B}$ will perform circular motion.

Therefore, both A and R are true and R is the correct explanation of A.

47. When a charge particle q is released from rest $(u = 0)$ in the uniform magnetic field B, then magnetic force on the charged particle $F = Bqu \sin\theta = 0$, because $u = 0$. Therefore, the charge particle will not move on a circular path.

In the magnetic field, force on charge particle always acts in perpendicular direction to the direction of velocity of charge particle. Therefore, work done by magnetic field on charge particle is zero because force, $F = 0$.

Therefore, A is false and R is also false.

48. When a charged particle travels from outside in a magnetic field, the particle moves out without completing a circle.

In case, a charged particle is moving perpendicular to magnetic field, power associated will be zero.

Therefore, A is true but R is false.

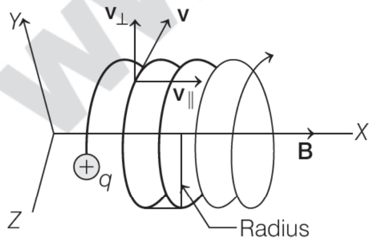
49. The path will be uniform circle, only if field is uniform and angle between v and B is 90°.

Therefore, A is true but R is false.

50. When a charged particle moves in a region of magnetic field, such that its velocity is at some acute angle with the direction of field, then it has a parallel component and a perpendicular component to the field.

The perpendicular component of velocity results in a Lorentz force $(\mathbf{v} \times \mathbf{B})$, which is also perpendicular to the plane containing $\mathbf{v}$ and $\mathbf{B}$. This provides the necessary centripetal force and thus, the particle has a tendency to perform circular motion.

Hence, the perpendicular component of velocity causes a rotating centripetal force and parallel component of velocity does not produced any force and the resulting trajectory is a helix as shown



Therefore, both A and R are true and R is the correct explanation of A.

51. Here, magnetic force, $\mathbf{F}_m = 0$, if $\theta = 0°$ or $180°$

Further, if $\mathbf{F}_e + \mathbf{F}_m = 0$ or $q\,\mathbf{E} + q(\mathbf{v} \times \mathbf{B}) = 0$

Path is undeflected.

Therefore, both A and R are true but R is not the correct explanation of A.

52. Kinetic energy will remain constant, if

$$\mathbf{F}_e + \mathbf{F}_m = 0$$

Net force experienced by a moving charge in presence of both electric and magnetic fields is

$$\mathbf{F} = q\,\mathbf{E} + q\,(\mathbf{v} \times \mathbf{B})$$

Therefore, both A and R are true, but R is not the correct explanation of A.

53. Magnetic force of attraction on lower wire is upwards while its weight is downwards. At a certain distance x these two forces are equal.

If the lower wire is displaced upwards from the position, then the magnitude of magnetic force will increase but its weight will remain same. Therefore, net force is upward or equilibrium is unstable.

Therefore, A is true but R is false.

54. Torque experienced by a current carrying loop in a uniform magnetic field is $\tau = \mathbf{m} \times \mathbf{B}$

Torque will be maximum when the magnetic moment m is perpendicular to magnetic field B. i.e. $\tau = mB$.

Therefore, A is true but R is false.

55. The deflection in a moving coil galvanometer is given by

$$\phi = \left(\frac{NAB}{k}\right) I$$

The needle in the galvanometer deflection whenever a current is passing through the coil.

Therefore, both A and R are true but R is not the correct explanation of the A.

56. Current sensitivity, $I_S = \dfrac{NBA}{k}$

$$I_S \propto N$$

and voltage sensitivity, $V_S = \dfrac{NBA}{kR}$

$$V_S \propto \frac{N}{R}$$

So, when I_S is increased by increasing the number of turns N, length of wire used also increases and so resistance R increases.

Hence, V_S may remain same or decrease whereas I_S increases.

Therefore, A is true but R is false.

57. As, $r_0 = \dfrac{mv_0}{qB}$

$\Rightarrow \quad r' = \dfrac{m\,(2v_0)}{qB} = 2\,r_0$

58. As, $T_0 = \dfrac{2\pi m}{qB}$

Thus, it remains same as it is independent of velocity.

59. As, $F \perp B$

Hence, $a \perp B$

$\therefore \quad \mathbf{a} \cdot \mathbf{B} = 0$

$\Rightarrow \quad (x\mathbf{i} + 2\hat{\mathbf{j}}) \cdot (2\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) \times 10^2 = 0$

$2x + 8 = 0$

$\Rightarrow \quad x = -4$

60. If the charged particle has a velocity not in a direction perpendicular to **B**, then component of velocity along **B** remains unchanged as the motion along, it will not be affected by **B**.

Then, the motion of the particle in a plane perpendicular to **B** will remain in circular path. Hence, it results in helical motion.

61. The force on electron, $F = qvB \sin\theta$

The electron is moving parallel to the **B**, so $\theta = 0°$.

$\Rightarrow \quad F = qvB \sin 0° = 0$

62. Force on charged particle in a magnetic field is given by $\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$

Since, $v = 0, F = 0$

Hence, option (c) is correct.

63. A moving charge experiences a force in an external magnetic field. The charge traverses along the helical path.

64. Since, the velocity vector of the β-rays are parallel to the direction of the magnetic field. β-rays will not get deflected.

65. The dipole will start rotating as it will experience a torque in the magnetic field. Since, it has non-zero kinetic energy, the velocity of the dipole in magnetic field will remain constant and it will move along with the magnetic field.

66. Force of charged particle, $F = qvB \sin\theta$

Force will be maximum, if $\theta = 90°$

i.e. if v is perpendicular to B.

67. $n = 400$, $I = 1.5$ A

$$B = \mu_0 nI = 4\pi \times 10^{-7} \times 400 \times 1.5$$
$$= 7.536 \times 10^{-7}$$
$$= 0.753 \text{ mT} \approx 0.8 \text{ mT}$$

68. The magnetic field of a solenoid having n turns and I current is $B = \mu_0 nI$.

When a soft iron of μ_r permeability is introduced, the magnetic field increases. Thus, $B = \mu_0 \mu_r nI$.

69. The strength of magnetic field reduces as the length of solenoid is decreased. Rest option increases the strength of magnetic field inside a solenoid.

70. There are no magnetic lines of force outside a solenoid. Hence, the magnetic field outside a solenoid is zero.

71. Magnetic field lines at the centre of the solenoid are straight lines as magnetic field inside a solenoid is uniform.

72. A moving coil galvanometer is used to measure current upto nanoampere. It shows deflection whenever a current is passed through the coil.

73. Uniform field is made radial by cutting pole pieces cylindrically.

74. The deflection in a moving coil galvanometer, $\phi = \dfrac{NAB}{k} \cdot I$ or $\phi \propto N$, where N is number of turns in a coil, B is magnetic field and A is area of cross-section.

75. The deflecting torque acting on the coil,

$$\tau_{\text{deflection}} = NIAB$$

76. Current sensitivity of galvanometer,

$$I_s = \frac{\phi}{I} = \frac{NBA}{k}$$

Hence, to increase (current sensitivity) I_S, (torsional constant of spring) k must be decreased.

05

Magnetism and Matter

Quick Revision

1. **Magnetic Dipole Moment of a Magnetic Dipole** is given by $\mathbf{M} = m(2\mathbf{l})$

   where, m is pole strength and $2\mathbf{l}$ is dipole length (magnetic length).

   The SI unit of magnetic dipole moment is A-m^2 or J/T.

   It is a vector quantity and its direction is from south pole towards north pole.

2. **Current Loop as a Magnetic Dipole** Current loop behaves like a magnetic dipole, whose dipole moment is given by

   $$\mathbf{M} = I\,\mathbf{A}$$

   The direction of dipole moment can be obtained by right hand thumb rule.

3. **Magnetic Dipole Moment of a Revolving Electron** $M = \dfrac{evr}{2}$

   where, v = speed of electron on a circular path of radius r.

   or $\qquad M = \dfrac{e}{2m_e} L$

   where, L = angular momentum and given as $L = m_e vr$ and m_e = mass of electron.

4. **Magnetic Lines of Forces** Magnetic lines of forces are closed curves and they do not intersect with each other.

   Magnetic lines of forces point away from north pole to south pole outside the magnet and point from south pole to north pole inside the magnet.

5. **Earth's Magnetic Field** Earth behaves like a magnet whose magnetic north pole is somewhere close to the geographical south pole and the magnetic south pole is closed to the geographical north pole.

6. There are three **elements of earth's magnetic field** namely
   - Angle of declination (α)
   - Angle of dip (δ)
   - Horizontal component of earth's magnetic field (H_e).

7. The angle between geographical meridian and magnetic meridian is known as **angle of declination** (α).

8. In magnetic meridian, the angle made by resultant earth's magnetic field (B_e) with the horizontal is known as **angle of dip** (δ).

9. Horizontal component of the earth's magnetic field, $\quad H_e = B_e \cos\delta$

   Vertical component of the earth's magnetic field,

   $$V_e = B_e \sin\delta$$

10. Relationship between horizontal & vertical components of the earth's magnetic field and angle of dip is given by

    $$H_e = B_e \cos\delta \text{ and } V_e = B_e \sin\delta$$

    So, $\qquad \dfrac{V_e}{H_e} = \tan\delta$

    and $\qquad B_e = \sqrt{V_e^2 + H_e^2}$

Objective Questions

Multiple Choice Questions

1. A natural bar magnet
(a) is always suspended in north-south direction
(b) always has two poles
(c) is made of iron and its alloys
(d) All of the above

2. The relation between the magnetic length (L_e) and the geometric length (L_g) is best represented by
(a) $L_e > L_g$
(b) $L_e = L_g$
(c) $L_e < L_g$
(d) $L_e = L_g = \infty$

3. Two magnets have the same length and the same pole strength. But one of the magnets has a small hole at its centre. Then,
(a) both have equal magnetic moment
(b) one with hole has small magnetic moment
(c) one with hole has large magnetic moment
(d) one with hole loses magnetism through the hole

4. Magnetic lines of force due to a bar magnet do not intersect, because
(a) a point always has a single net magnetic field
(b) the lines have similar charges and so repel each other
(c) the lines always diverge from a single point
(d) None of the above

5. If the magnet is cut into four equal parts, such that their lengths and breadths are equal, then pole strength of each part is
(a) m (b) $\frac{m}{2}$
(c) $\frac{m}{4}$ (d) $\frac{m}{8}$

6. A bar magnet of magnetic moment M_1 is axially cut into two equal parts. If these two pieces are arranged perpendicular to each other, the resultant magnetic moment is M_2, then the value of M_1/M_2 is
(a) $\frac{1}{2\sqrt{2}}$ (b) 1 (c) $\frac{1}{\sqrt{2}}$ (d) $\sqrt{2}$

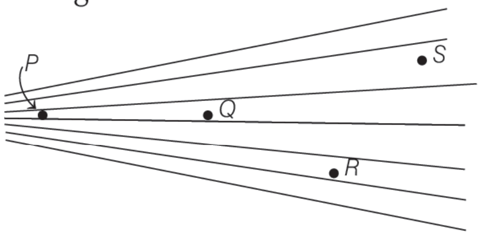
7. Electron is revolving around a nucleus in circular orbit of radius 1 Å with a speed 4×10^4 m/s. Magnetic moment produced due to rotation of electron is
(a) 3.2×10^{-29} A-m^2 (b) 6.4×10^{-25} A-m^2
(c) 3.2×10^{-25} A-m^2 (d) 1.6×10^{-5} A-m^2

8. Magnetic moment of an electron in the first orbit is
(a) $\frac{2eh}{4\pi m_e}$ (b) $\frac{eh}{4\pi m_e}$
(c) $\frac{eh}{2\pi m_e}$ (d) None of these

9. Which of the following expression represents the relation between orbital magnetic moment and orbital angular momentum of an electron?
(a) $\mu_{orb} = -\frac{2m_e}{e} L_{orb}$ (b) $\mu_{orb} = -2m_e L_{orb}$
(c) $\mu_{orb} = -\frac{e}{2m_e} L_{orb}$ (d) $\mu_{orb} = \frac{e}{2m_e} L_{orb}$

10. An electron of charge e moves in a circular orbit of radius r around the nucleus at a frequency ν. The magnetic moment associated with the orbital motion of the electron is
(a) $\pi \nu e r^2$ (b) $\frac{\pi \nu r^2}{e}$
(c) $\frac{\pi \nu e}{r}$ (d) $\frac{\pi e r^2}{\nu}$

11. Which of the following point lies in the region of highest magnetic field strength ?



(a) P (b) Q
(c) R (d) S

12. At the same place, the horizontal component of earth's magnetic field is 0.40 G and the angle of dip is 30°. What is the resultant magnetic field?

(a) 0.46 G (b) 0.36 G
(c) 0.12 G (d) 0.14 G

13. The relations amongst the three elements of earth's magnetic field namely : horizontal component H_e, vertical component V_e and angle of dip δ are (B_e = total magnetic field)

(a) $V_e = B_e \tan\delta, H_e = B_e$
(b) $V_e = B_e \sin\delta, H_e = B_e \cos\delta$
(c) $V_e = B_e \cos\delta, H_e = B_e \sin\delta$
(d) $V_e = B_e, H_e = B_e \tan\delta$

14. The angle of dip at a certain place on the earth is 60° and the magnitude of the earth's horizontal component of magnetic field is 0.26 G. The magnetic field at the place on the earth is

(a) 0.13 G (b) 0.26 G
(c) 0.52 G (d) 0.65 G

15. The magnetic field of the earth can be modelled by that of a point dipole placed at the centre of the earth. The dipole axis makes an angle of 11.3° with the axis of the earth. At Mumbai, declination is nearly zero. Then, ***(NCERT Exemplar)***

(a) the declination varies between 11.3° W to 11.3° E
(b) the least declination is 0°
(c) the plane defined by dipole axis and the earth axis passes through Greenwich
(d) declination averaged over the earth must be always negative

16. At a place in magnetic meridian, magnetic needle bends 30° from horizontal. If earth's magnetic field at this place is 2 G, then vertical component and horizontal component of earth's magnetic field respectively, are

(a) 10^{-4}T, $\sqrt{2}\times10^{-4}$T
(b) 10^{-4}T, $\sqrt{3}\times10^{-4}$ T
(c) $\sqrt{3}\times10^{-4}$T, 10^{-4}T
(d) $\sqrt{3}\times10^{-4}$T, $\sqrt{2}\times10^{-4}$T

17. Angle of dip is maximum at

(a) pole (b) equator
(c) Both (a) and (b) (d) Neither (a) nor (b)

18. A current loop behaves as a system of ………… . As a result, it acts like an magnetic dipole.

(a) magnetic pole (b) charges
(c) Both (a) and (b) (d) None of these

19. The magnetic field produced by a ………… on any point on the axial line is same as that of a bar magnet.

(a) solenoid (b) toroid
(c) straight wire (d) dipole

20. Which of the following statement(s) is/are correct ?

(a) Magnetic phenomena are not universal in nature.
(b) The name lodestone (or loadstone) given to a naturally occurring ore of iron magnetite means leading stone.
(c) A bar magnet is not analogous to a solenoid.
(d) The magnetic field lines are discontinuous, emerging from one face of the solenoid to the infinity.

21. Which of the following statement (s) is/are correct with respect of magnetic lines of forces?

(a) Magnetic lines of forces are discontinuous curves.
(b) Magnetic lines of forces do not intersect to each other.
(c) Magnetic lines of forces always enter into south pole from its outside region.
(d) Both (b) and (c)

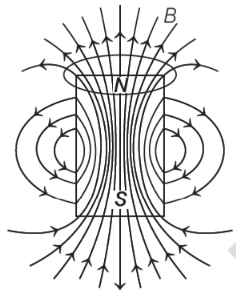
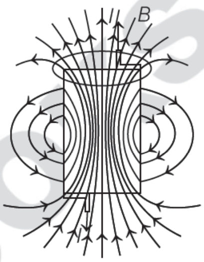
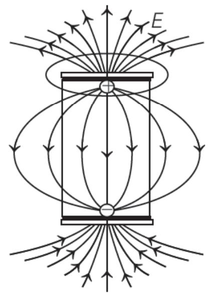
22. Which of the following statement(s) is/are incorrect?

(a) The magnetic field lines of a magnet (or a solenoid) form continuous closed loops. This is unlike the electric dipole, where these field lines begin from a positive charge and end on the negative charge or escape to infinity.
(b) The tangent to the field line at a given point represents the direction of the net magnetic field *B* at that point.
(c) The larger the number of field lines crossing per unit area, the stronger the magnitude of the magnetic field *B*.
(d) We can isolate the north or south pole of a magnet.

23. Which of the following statement(s) is/are correct ?

(a) The horizontal plane containing the longitude circle and the axis of rotation of the earth is called magnetic meridian.
(b) The angle between the true geographic north and the south shown by a compass needle is called the magnetic declination or simple declination.
(c) The declination is smaller at higher latitudes and greater near the equator.
(d) Dip is the angle that the total magnetic field B_e of the earth makes with the surface of the earth.

24. Match the Column I (magnetic/electric field pattern) with Column II (name of object producing magnetic/electric field) and select the correct answer from the codes given below

	Column I		Column II
A.		p.	The field lines of a current carrying finite solenoid
B.		q.	A field lines of electric dipole
C.		r.	The field lines of a bar magnet

Codes

	A	B	C		A	B	C
(a)	q	p	r	(b)	r	p	q
(c)	p	q	r	(d)	q	r	p

Assertion/Reasoning MCQs

*For question numbers 25 to 28, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

25. **Assertion** The poles of magnet cannot be separated by breaking into two pieces.

Reason The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.

26. **Assertion** Basic difference between an electric line and magnetic line of force is that former is discontinuous and the latter is continuous or endless.

Reason No electric lines of forces exist inside a charged conductor but magnetic lines do exist inside a magnet.

27. **Assertion** According to Gauss's law for magnetism, the net magnetic flux through any closed surface is zero.

Reason The number of magnetic field lines leaving the surface is balanced by the number of lines entering it.

28. **Assertion** The true geographic north direction can be found by using a compass needle.

Reason The magnetic meridian of the earth is along the axis of rotation of the earth.

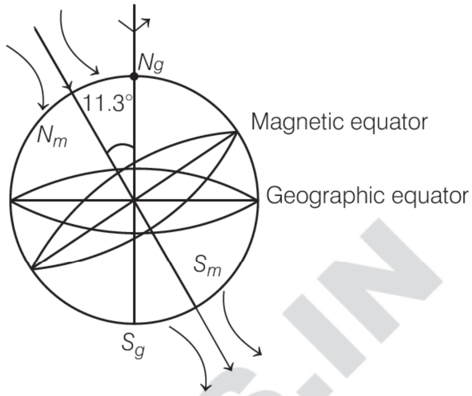
Case Based MCQs

Direction *Answer the questions from 29-33 on the following case.*

Earth's Magnetic Field

The magnetic field lines of the earth resemble that of a hypothetical magnetic dipole located at the centre of the earth. The axis of the dipole is presently tilted by approximately 11.3° with respect to the axis of rotation of the earth.

The pole near the geographic north pole of the earth is called the north magnetic pole and the pole near the geographic south pole is called south magnetic pole.



29. The strength of the earth's magnetic field varies from place-to-place on the earth's surface, its value being of the order of

(a) 10^5 T (b) 10^{-6} T
(c) 10^{-5} T (d) 10^8 T

30. A bar magnet is placed north-south with its north pole due north. The points of zero magnetic field will be in which direction from centre of magnet?

(a) North-South
(b) East-West
(c) North-West and South-East
(d) North-East and South-West

31. The value of angle of dip is zero at the magnetic equator because on it

(a) the values of V_e and H_e are equal
(b) the values of V_e and H_e are zero
(c) the value of V_e is zero
(d) the value of H_e is zero

32. The angle of dip at a certain place, where the horizontal and vertical components of the earth's magnetic field are equal, is

(a) 30° (b) 90°
(c) 60° (d) 45°

33. At a place, angle of dip is 30°. If horizontal component of earth's magnetic field is H_e, then the total intensity of magnetic field will be

(a) $H_e/2$ (b) $2H_e/\sqrt{3}$
(c) $H_e\sqrt{3/2}$ (d) $2H_e$

Direction *Answer the questions from 34-38 on the following case.*

Gauss Law in Magnetism

We can write Gauss's law for magnetostatics as $\int \mathbf{B} \cdot d\mathbf{A} = \mu_0 m$,

where, $\int \mathbf{B} \cdot d\mathbf{A}$ is the magnetic flux and m is the net magnetic pole strength inside a closed surface.

It was found that, magnetic flux through a closed surface is always zero, thus we reach at a conclusion that magnetic monopoles do not exist. A bar magnet always attain north-south poles no matter how many times it is cut into pieces.

34. The net magnetic flux due to a bar magnet over a closed surface is

(a) zero (b) $\frac{\mu_0}{4\pi}$

(c) $4\pi\mu_0$ (d) $\frac{4\mu_0}{\pi}$

35. The presence of magnetic monopoles is ruled out by

(a) Gauss's law of electrostatics

(b) Gauss's law for magnetism

(c) Faraday's law

(d) Ampere's circuital law with Maxwell's addition

36. A bar magnet is separated four times, the number of monopoles and dipoles formed are

(a) 0, 8 (b) 0, 4 (c) 8, 2 (d) 8, 1

37. The number of magnetic field lines passing through a surface area normally is called

(a) magnetic field (b) electric field

(c) magnetic flux (d) electric flux

38. The dimensional representation of magnetic flux density is

(a) $[MLT^{-2}]$ (b) $[MLT^{-2}A^{-1}]$

(c) $[MT^{-2}A^{-1}]$ (d) $[MLT^{-2}A^{2}]$

ANSWERS

Multiple Choice Questions

1. (d)	*2. (c)*	*3. (b)*	*4. (d)*	*5. (b)*	*6. (d)*	*7. (c)*	*8. (b)*	*9. (c)*	*10. (a)*
11. (a)	*12. (a)*	*13. (b)*	*14. (c)*	*15. (a)*	*16. (b)*	*17. (a)*	*18. (a)*	*19. (a)*	*20. (b)*
21. (d)	*22. (d)*	*23. (d)*	*24. (b)*						

Assertion/Reasoning MCQs

25. (b)	*26. (b)*	*27. (a)*	*28. (d)*

Case Based MCQs

29. (c)	*30. (b)*	*31. (c)*	*32. (d)*	*33. (b)*	*34. (a)*	*35. (b)*	*36. (b)*	*37. (c)*	*38. (c)*

SOLUTIONS

1. A natural bar magnet consists of two poles, i.e. north and south poles. It points in the north-south direction. It is a composition of iron and its alloys.

So, all the options are correct.

2. The distance between two poles of a bar magnet is known as the magnetic length (L_e). However, the actual length of a bar magnet is known as the geometric length (L_g).

Since, the relation between them is given by

$$L_e = \left(\frac{5}{6}\right) L_g$$

i.e. $\quad L_e < L_g$

3. As, we know, magnetic dipole moment $\mathbf{M} = m(2\mathbf{l})$, so hole reduces the effective length of the magnet and hence magnetic moment reduces.

4. Magnetic lines of force due to a bar magnet do not intersect, because if they intersect then it means, there are two directions of magnetic field intensity at the point of intersection which is impossible.

5. If the magnet is cut into four equal parts and their lengths and breadths are equal, then pole strength for each part is

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

6. Initial magnetic moment $= M_1$

When cut in two parts, magnetic moment of each part

$$M' = \frac{M_1}{2}$$

When both parts are placed perpendicular to each other, effective magnetic moment,

$$M_2 = \sqrt{(M')^2 + (M')^2} = \sqrt{2}M' = \sqrt{2} \times \frac{M_1}{2}$$

$$\therefore \quad \frac{M_1}{M_2} = \frac{2}{\sqrt{2}} = \sqrt{2}$$

7. Given, $r = 1\,\text{Å} = 1 \times 10^{-10}\,\text{m}$

and $\quad v = 4 \times 10^4\ \text{m/s}$

Magnetic moment associated due to revolution of electron.

$$\mu = \frac{evr}{2} = \frac{1.6 \times 10^{-19} \times 4 \times 10^4 \times 10^{-10}}{2} = 3.2 \times 10^{-25}\ \text{A-m}^2$$

8. We know that, magnetic moment of a revolving electron,

$$\mu = \frac{evr}{2} = \frac{e \cdot m_e vr}{2m_e}$$

$$\Rightarrow \quad \mu = \frac{eL}{2m_e} \qquad \ldots\text{(i)}$$

$$[\because L = m_e vr]$$

According to Bohr's quantisation condition,

$$L = \frac{nh}{2\pi} \qquad \ldots\text{(ii)}$$

From Eqs. (i) and (ii),

$$\mu = \frac{enh}{4\pi m_e}$$

For first orbit, $\quad n = 1$

$$\therefore \quad \mu = \frac{eh}{4\pi m_e}$$

9. As, $\dfrac{\mu_{\text{orb}}}{\mathbf{L}_{\text{orb}}} = \dfrac{\frac{-evr}{2}}{m_e vr} = \dfrac{-e}{2m_e}$

$$\Rightarrow \quad \mu_{\text{orb}} = \frac{-e}{2m_e}\mathbf{L}_{\text{orb}}$$

where, μ_{orb} = orbital magnetic momentum

and $\quad \mathbf{L}_{\text{orb}}$ = orbital angular momentum.

10. Magnetic moment or magnetic dipole moment is given by

$$M = iA \qquad \ldots\text{(i)}$$

where, i is the current and A is the area.

The effective current, $i = \dfrac{e}{T}$

where, e is electronic charge and T is the time period.

Also, $\quad \nu = \dfrac{1}{T}$ = frequency

and area $A = \pi r^2$, where r is the radius of circular path.
Putting these values in Eq. (i), we get
$M = ev \cdot \pi r^2$.

11. The larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field strength. Since, here point P among the given point lies in the region which has maximum number of field lines crossing per unit area. Hence, point P lies in the region of highest magnetic field strength.

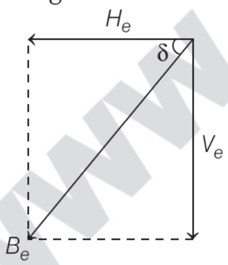
12. The vertical component of earth's magnetic field,

$$B_V = B_H \tan\theta$$
$$= 0.40 \times \tan 30° = 0.23 \text{ G}$$

The resultant magnetic field of earth,

$$B_e = \sqrt{B_H^2 + B_V^2}$$
$$= \sqrt{(0.40)^2 + (0.23)^2} = 0.46 \text{ G}$$

13. Let B_e be the net magnetic field at some point and H_e & V_e be the horizontal & vertical components of B_e. Let δ be the angle of dip, which is the angle between direction of earth's magnetic field B_e and horizontal line in the magnetic meridian.



Thus, from figure, we can see that

$$V_e = B_e \sin\delta$$

and $$H_e = B_e \cos\delta$$

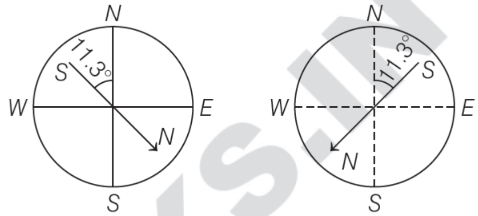
14. Horizontal component of the earth's magnetic field is the component of the earth's magnetic field along the horizontal direction.

So, $B_H = B_e \cos\delta$

$0.26 = B_e \cos 60°$

$\Rightarrow \quad B_e = \dfrac{0.26}{\cos 60°} = 0.52 \text{ G} \quad \left\{\because \cos 60° = \dfrac{1}{2}\right\}$

15. For the earth's magnetism, the magnetic field lines of the earth resemble that of a hypothetical magnetic dipole located at the centre of the earth.
The axis of the dipole does not coincide with the axis of rotation of the earth but is presently tilted by approximately 11.3° with respect to the later. This results into two situations as given in the figure ahead.



Hence, the declination varies between 11.3° W to 11.3° E.

16. Given, $\delta = 30°$

and $B_e = 2 \text{ G} = 2 \times 10^{-4} \text{ T}$

$\therefore$
$$B_V = B_e \sin\delta$$
$$= 2 \times 10^{-4} \sin 30°$$
$$= 2 \times 10^{-4} \times \frac{1}{2}$$
$$= 10^{-4} \text{ T}$$

$\therefore$
$$B_H = B_e \cos\delta$$
$$= 2 \times 10^{-4} \cos 30°$$
$$= 2 \times 10^{-4} \times \frac{\sqrt{3}}{2}$$
$$= \sqrt{3} \times 10^{-4} \text{ T}$$

17. At pole, only vertical component of earth's magnetic field exists.
Hence, $B_H = 0$

$\therefore \quad \tan\delta = \dfrac{B_V}{B_H} = \dfrac{B_V}{0} = \infty$

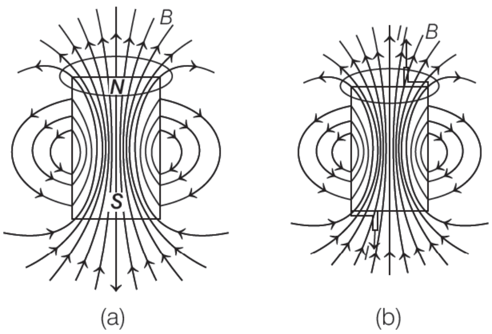
$\Rightarrow \quad \tan\delta = \tan 90°$

$\Rightarrow \quad \delta = 90°$

Since, $0 < \delta < 90°$.
Hence, angle of dip is maximum at pole.

18. A current loop behaves as a magnetic pole. If current is moving in anti-clockwise direction as seen from upper face, it acts like a north pole and lower face as south pole.

19. The magnetic field lines of a bar magnet and a current carrying solenoid resemble each other as shown below



(a) bar magnet

(b) current carrying finite solenoid

20. The statement given in option (b) is correct but rest are incorrect and these can be corrected as,

Magnetic phenomena are universal in nature.

The resemblance of magnetic field lines of a bar magnet and a solenoid suggest that a bar magnet may be thought of as a large number of circulating currents in analogy with a solenoid.

The magnetic field lines remain continuous, emerging from one face of the solenoid and entering into the other face.

21. Magnetic lines of forces are continuous curves. Magnetic lines of forces do not intersect each other. Magnetic lines of forces always enter into south pole from its outside region.

22. The statement (d) is incorrect and it can be corrected as,

We cannot isolate the north or south pole of a magnet. If a bar magnet is broken into two halves, we get two similar magnets with weaker properties. Unlike electric charges, isolated magnetic north and south poles known as magnetic monopoles do not exist.

23. The statement given in option (d) is correct but rest are incorrect and these can be corrected as,

The vertical plane containing the longitude circle and the axis of rotation of the earth is called the geographic meridian. While, magnetic meridian of a place is the vertical plane which passes through the imaginary line joining the magnetic north and the south poles.

The angle between the true geographic north and the north shown by a compass needle is called the magnetic declination or simple declination.

The declination is greater at higher latitudes and smaller near the equator.

24. A. Field lines shown in this field pattern are closed lines. The strongest external magnetic fields are near the poles. These field lines are less concentrated as compared to magnetic field pattern of magnetic field in Column I. Hence, it is the magnetic field pattern of a bar magnet.

B. Field lines shown in this field pattern are highly concentrated and form continuous close pattern. The strongest external magnetic field, is near the poles. Hence, this pattern of magnetic field resembles with field pattern of a solenoid where the ends of a solenoid behave as north and south poles of a magnet.

C. In this field pattern, the field lines are curved and extend from the positive to negative charge. In general, electric field lines always begin on a positive charge and end on a negative charge and do not start or stop in mid-space.

Hence, this is pattern of electric field of an electric dipole.

Hence, A $\rightarrow$ r, B $\rightarrow$ p and C $\rightarrow$ q.

25. The poles of magnet cannot be separated by breaking into two pieces.

If a bar magnet is broken into two halves, we get two similar bar magnets with somewhat weaker properties. As magnetic moment will be reduced to half, because magnetic dipole moment is directly proportional to the length between the poles.

Therefore, both A and R are true but R is not the correct explanation of A.

26. Magnetic field lines of a magnet form continuous closed loops. On the other hand, electric field lines are discontinuous. Inside the magnet, magnetic field lines are from south to north but inside a charged conductor, there is no electric field.

Therefore, both A and R are true but R is not the correct explanation of A.

27. The net magnetic flux passes through a closed surface enclosing a bar magnet is zero because a bar magnet has two poles (one north and other south) and the magnetic flux leaving the north pole is equal to the magnetic flux entering the south pole of bar magnet.

Thus, according to Gauss's law for magnetism, the net magnetic flux through any closed surface is zero, i.e. the net flux ϕ_B is $\phi_B = \sum_{\text{all}} \mathbf{B} \cdot \Delta \mathbf{S} = 0$.

Therefore, both A and R are true and R is the correct explanation of A.

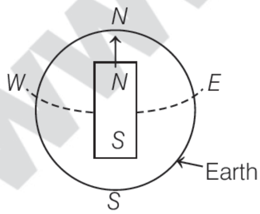
28. There is always an angle of declination between magnetic meridian and the geographic meridian. A compass is simply a needle shaped magnet, which always points in magnetic north-south poles (i.e. in magnetic meridian). Thus, true geographic north direction cannot be found by using a compass needle.

The magnetic meridian of the earth is defined by some angle from the axis of rotation of the earth.

Therefore, A is false and R is also false.

29. The strength of magnetic field on the surface is order of 10^{-5} T.

30. As shown in figure, points of zero magnetic field will be east-west.



31. The value of vertical component of earth's magnetic field is zero, when angle of dip is zero at magnetic equator.

$$\tan \phi = \frac{V_e}{H_e}$$

32. As, $\tan \phi = \dfrac{V_e}{H_e}$

$$\tan \phi = \frac{H_e}{H_e} \qquad (\because V_e = H_e)$$

$$\phi = 45^\circ \qquad (\tan^{-1} 45^\circ = 1)$$

33. Total intensity of magnetic field is given by

$$I \cos \theta = H_e$$

thus, $I \cos 30^\circ = H_e$

$$I \frac{\sqrt{3}}{2} = H_e \qquad \left(\because \cos 30^\circ = \frac{\sqrt{3}}{2}\right)$$

$$\Rightarrow \qquad I = \frac{2H_e}{\sqrt{3}}$$

34. The net magnetic pole strength of a bar magnet is $m_N + m_S = 0$. Hence, magnetic flux due to bar magnet over a closed surface is zero.

35. According to Gauss's law of magnetism, the net magnetic flux of the magnetic field must always be zero over any closed surface. It means there is no existence of magnetic monopoles.

36. If a bar magnet is separated into four different bar magnets, all four magnets will have their own north-south poles. Hence, there will be zero monopoles and four dipoles.

37. The number of magnetic field lines passing through a surface area is called magnetic flux. It is denoted by ϕ_B and measured in weber (Wb).

38. The dimensional formula for the magnetic flux is

$$\phi_B = [\mathrm{M^1 L^3 T^{-2} A^{-1}}]$$

Dimensional formula for the volume,

$$V = [\mathrm{L^3}]$$

Dimensional representation of magnetic flux density $= \dfrac{\phi_B}{V}$

$$= \frac{[\mathrm{M^1 L^3 T^{-2} A^{-1}}]}{[\mathrm{L^3}]} = [\mathrm{MT^{-2} A^{-1}}]$$

06

Electromagnetic Induction

Quick Revision

1. **Magnetic flux** linked with any surface is equal to the total number of magnetic lines of force passing through it. It is a scalar quantity.

   The SI unit of magnetic flux is weber (Wb) and CGS unit is maxwell (Mx).

   $$1 \text{ Wb} = 10^8 \text{ Mx}$$

2. **Faraday's Law of Electromagnetic Induction** Whenever magnetic flux linked with the closed loop or circuit changes, an emf is induced in the loop or circuit.

   Mathematically the induced emf in a closed loop or circuit, is directly proportional to the rate of change of magnetic flux linked with the closed loop or circuit.

   i.e. $e \propto \dfrac{d\phi}{dt} \Rightarrow e = -N\dfrac{d\phi}{dt}$

   where, N = number of turns in loop.

   Negative sign indicates the Lenz's law.

3. **Lenz's Law** The direction of induced emf or induced current is such that it always opposes the cause that produced it, i.e. change in magnetic flux linked with the circuit.

   Lenz's law is a consequence of the law of conservation of energy.

   Induced current, $I = \dfrac{e}{R} = -\dfrac{N}{R} \cdot \dfrac{d\phi_B}{dt}$

4. **Motional emf** The emf ε induced in a conductor of length l moving with velocity v in a direction perpendicular to magnetic field B is given by

   $$\varepsilon = vBl$$

5. The induced emf developed between two ends of conductor of length l rotating with angular velocity ω about one end in a direction perpendicular to magnetic field B is given by

   $$\varepsilon = \frac{B\omega l^2}{2}$$

6. emf can be induced in a coil by
   - moving the coil/loop/circuit in varying magnetic field.
   - changing the area A of the coil inside the magnetic field.
   - changing the angle θ between **B** and **A**.

7. **Eddy Currents** These are loops of electric current induced within bulk pieces of conductors by a changing magnetic field in the conductor, according to Faraday's law of electromagnetic induction. It causes the heating of conductor.

8. **Self-induction** is the phenomenon of production of induced emf in a coil itself, when a current passing through it changes continuously.

$\because$ Total flux linked with coil, $N\phi \propto I$

$\therefore \quad N\phi = LI$

where, ϕ = flux linked with each turn,

L = coefficient of self-induction

and N = number of turns in the coil.

Also, induced emf, $e = -L\dfrac{dI}{dt}$

The SI unit of inductance is henry (H).

1 henry (H) = 1 V-s/A

= 1 WbA^{-1}

9. Equivalent inductance of two inductors are in parallel combination, $\dfrac{1}{L} = \dfrac{1}{L_1} + \dfrac{1}{L_2}$

10. Equivalent inductance of two inductors are in series combination, $L = L_1 + L_2$

11. Self-inductance of a long solenoid, $L = \dfrac{\mu N^2 A}{l}$

where, μ = magnetic permeability of the medium inside the solenoid,

N = number of turns,

A = area of solenoid

and l = length of solenoid.

12. **Mutual Induction** is the phenomenon of generation of induced emf in secondary coil, when current linked with primary coil changes

$\therefore \quad N_2\phi_2 = MI_1$

where, $N_2\phi_2$ = flux linked with secondary coil,

I_1 = current in primary coil

and M = constant = mutual inductance or coefficient of mutual induction.

Also, $e_2 = -M\dfrac{dI_1}{dt}$

13. Mutual inductance of closely wound solenoids,

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

where, N_1 & N_2 = number of turns in primary & secondary solenoids, A = area of solenoid and l = length of solenoid.

14. The capacity of an inductor to store energy in a magnetic field is the **magnetic energy stored in an inductor**.

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

where, I is current in inductor and L is inductance of coil.

15. The energy stored per unit volume (V) in a magnetic field (B) is known as **energy density**.

$\therefore$ Energy density $= \dfrac{U}{V} = \dfrac{1}{2}\dfrac{B^2}{\mu_0}$

Objective Questions

Multiple Choice Questions

1. The dimensions of magnetic flux are

(a) $[MLT^{-2}A^{-2}]$
(b) $[ML^2T^{-2}A^{-2}]$
(c) $[ML^2T^{-1}A^{-2}]$
(d) $[ML^2T^{-2}A^{-1}]$

2. A square of side L metres lies in the xy-plane in a region, where the magnetic field is given by $\mathbf{B} = B_0(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 4\hat{\mathbf{k}})$ T, where B_0 is constant. The magnitude of flux passing through the square is ***(NCERT Exemplar)***

(a) $2B_0L^2$ Wb (b) $3B_0L^2$ Wb
(c) $4B_0L^2$ Wb (d) $\sqrt{29}B_0L^2$ Wb

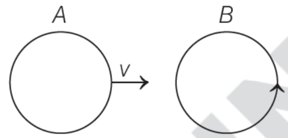
3. A circular disc of radius 0.2 m is placed in a uniform magnetic field of induction $(1/\pi)$ Wbm^{-2} in such a way that its axis makes an angle of 60° with **B**. The magnetic flux linked with the disc is

(a) 0.02 Wb (b) 0.06 Wb
(c) 0.08 Wb (d) 0.01 Wb

4. According to Faraday's law of electromagnetic induction, the magnitude of the induced emf in a circuit is equal to the time rate of change of ....

(a) magnetic field induction
(b) magnetising field intensity
(c) magnetic flux
(d) electric flux

5. There are two coils A and B as shown in figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counter clockwise. B is kept stationary when A moves. We can infer that there is ***(NCERT Exemplar)***



(a) a constant current in the clockwise direction in A
(b) a varying current in A
(c) no current in A
(d) a constant current in the counter clockwise direction in A

6. The flux linked with a circuit is given by $\phi_B = t^2 + 2$. The graph between time (X-axis) and induced emf (Y-axis) will be a

(a) straight line through the origin
(b) straight line with positive intercept
(c) straight line with negative intercept
(d) parabola not through the origin

7. A square loop of wire, side length 10 cm is placed at angle of 45° with a magnetic field that changes uniformly from 0.1T to zero in 0.7s. The induced current in the loop (its resistance is 1Ω) is

(a) 1.0 mA (b) 2.5 mA (c) 3.5 mA (d) 4.0 mA

8. Lenz's law of electromagnetic induction corresponds to the law of conservation of

(a) charge
(b) energy
(c) momentum
(d) angular momentum

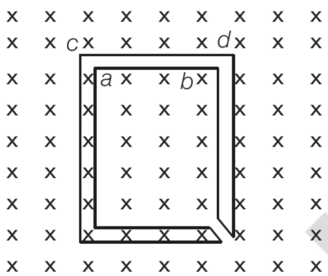
9. The North-pole of a long horizontal bar magnet is being brought closer to a vertical conducting plane along the perpendicular direction. The direction of induced current in the conducting plane will be

(a) horizontal (b) vertical
(c) clockwise (d) anti-clockwise

10. An infinitely long cylinder is kept parallel to a uniform magnetic field B directed along positive Z-axis. The direction of induced current as seen from the Z-axis will be

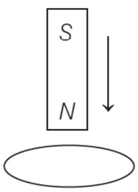
(a) clockwise of the positive Z-axis
(b) anti-clockwise of the positive Z-axis
(c) zero, no current is induced
(d) along the magnetic field

11. The figure shows certain wire segments joined together to form a co-planar loop. The loop is placed in a perpendicular magnetic field in the direction going into the plane of the figure. The magnitude of the field increases with time and I_1 & I_2 are the currents in the segment ab & cd. Then,



(a) $I_1 > I_2$
(b) $I_1 < I_2$
(c) I_1 is in the direction ba and I_2 is in the direction cd
(d) I_1 is in the direction ba and I_2 is in the direction dc

12. The North-pole of a magnet is falling on a metallic ring as shown in the figure. The direction of induced current, if looked from upside, in the ring will be

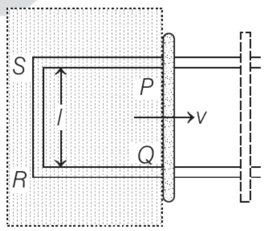


(a) clockwise or anti-clockwise depending on metal of the ring
(b) non induced current
(c) anti-clockwise
(d) clockwise

13. A conducting rod of length l is falling with a constant velocity v perpendicular to a uniform horizontal magnetic field B. The potential difference between its two ends will be

(a) $2Blv$ (b) Blv
(c) $\frac{1}{2}Blv$ (d) $B^2l^2v^2$

14. A rectangular conductor $SPQR$ is placed in a uniform magnetic field perpendicular to the plane and extending from $x = 0$ to $x = b$ as shown below. The arm PQ of length l is moving from $x = 0$ to $x = 2b$ with constant speed v. Find the flux and emf induced in the conductor.



(a) $Blx, -Blv$, when $0 \le x < b$
(b) $2Bl, -2Bl$
(c) $Blb, 0$, when $b \le x < 2b$
(d) Both (a) and (c)

15. The magnitude of the earth's magnetic field at a place is B_0 and the angle of dip is δ. A horizontal conductor of length L lying in magnetic North-South moves eastwards with a velocity v. The emf induced across the conductor is

(a) zero
(b) $B_0 Lv \sin\delta$
(c) $B_0 Lv$
(d) None of the above

16. A circular coil of mean radius of 7 cm and having 4000 turns is rotated at the rate of 1800 rev/min in the earth's magnetic field $(B = 0.5\ \text{G})$, the maximum emf induced in coil will be

(a) 1.158 V (b) 0.57 V
(c) 0.29 V (d) 5.8 V

17. Eddy currents are produced, when
(a) a metal is kept in varying magnetic field
(b) a metal is kept in a steady magnetic field
(c) a circular coil is placed in a magnetic field
(d) through a circular coil current is passed

18. In induction furnace, heat is produced due to
(a) eddy currents (b) resistance
(c) capacitor (d) None of these

19. Which of the following is not an application of eddy currents?
(a) Induction furnace
(b) Galvanometer damping
(c) Speedometer of automobiles
(d) X-ray crystallography

20. Amongst the following physical parameter, which is equivalent to self-induction?
(a) Inertia of mass
(b) Inertia of energy
(c) Inertia of moment
(d) Inertia of current

21. The self-inductance of a coil having 500 turns is 50 mH. The magnetic flux through the cross-sectional area of the coil while current through it is 8 mA, is found to be
(a) 4×10^{-4} Wb (b) 0.04 Wb
(c) 4μ Wb (d) 40 m Wb

22. If emf induced in a coil is 2 V by changing the current in it from 8 A to 6 A in 2×10^{-3} s, then the coefficient of self-induction is
(a) 2×10^{-3} H (b) 10^{-3} H
(c) 0.5×10^{-3} H (d) 4×10^{-3} H

23. A long solenoid has 1000 turns. When a current of 4 A flows through it, the magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self-inductance of the solenoid is
(a) 3 H (b) 2 H
(c) 1 H (d) 4 H

24. A coil and a bulb are connected in series with a DC source, a soft iron core is inserted in the coil, then the intensity of the bulb
(a) remains the same (b) decreases
(c) increases (d) zero

25. The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60 mA. This inductor is of inductance
(a) 1.389 H (b) 138.88 H
(c) 0.138 H (d) 13.89 H

26. The mutual inductance M_{12} of coil 1 with respect to coil 2
(a) increases, when they are brought nearer
(b) depends on the current passing through the coils
(c) increases, when one of them is rotated about an axis
(d) is different from M_{21} of coil 2 with respect to coil 1

27. There are two long co-axial solenoids of same length l. The inner & outer coils have radii r_1 & r_2 and number of turns per unit length n_1 & n_2, respectively. The ratio of mutual inductance to the self-inductance of the inner coil is
(a) $\frac{n_2}{n_1} \cdot \frac{r_1}{r_2}$ (b) $\frac{n_2^2}{n_1^2} \cdot \frac{r_2^2}{r_1^2}$ (c) $\frac{n_2}{n_1}$ (d) $\frac{n_1}{n_2}$

28. When the magnetic flux linked with a conducting wire loop changes with time, an ………… is induced in the cable.
(a) potential difference (b) electric field
(c) current (d) emf

29. In electromagnetic induction, the induced charge in a coil is independent of ………… .
(a) flux change
(b) time taken to change the flux
(c) resistance
(d) None of the above

30. If the resistance of a conductor is infinite. The power required to move a conductor in a uniform magnetic field is ....

(a) infinite (b) zero
(c) 1 W (d) None of these

31. The core of a transformer is laminated to reduce ....

(a) flux leakage
(b) output power
(c) hysteresis
(d) eddy current

32. The self-inductance of a coil is L. Keeping the length and area same, the number of turns in the coil is increased to four times. The self-inductance of the coil will be ....

(a) $\frac{L}{4}$ (b) L
(c) $4L$ (d) $16L$

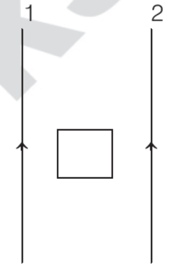
33. Which of the following statement(s) is/are incorrect?

(a) Flux can be varied by changing any one or more of the term B, A and θ.
(b) Flux can also be altered by changing the shape of a coil (i.e. by shrinking it or stretching it) in a magnetic field.
(c) A gentle push on the magnet in magnetic field intiates the motion in magnet and its kinetic energy continuously increases without expanding any energy.
(d) When a bar magnet experiences a repulsive force due to the induced current, a person has to do work in moving the magnet. The energy spent by the person is dissipated by joule heating produced by the induced current.

34. Which of the following statement(s) is/are incorrect?

(a) The induced currents produced in a conductor due to changing magnetic flux is called eddy current.
(b) If rectangular slots are made in a copper plate, the electromagnetic damping decreases.
(c) The plane of the lamination of metal core must be arranged perpendicular to the magnetic field.
(d) The magnetic braking effect in trains is smooth.

35. A square loop is symmetrically placed between two infinitely long current carrying wires in the same direction. Magnitude of currents in both the wires are same. Now, match the Column I with Column II and select the correct answer from the codes given below

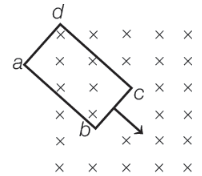
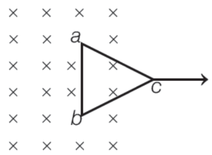
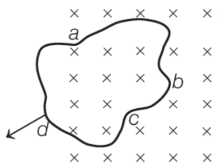


	Column I		Column II
A.	Loop is moved towards right	p.	Induced current in the loop is clockwise.
B.	Loop is moved towards left	q.	Induced current in the loop is anti-clockwise.
C.	Wire-1 is moved towards left	r.	Power in the loop is zero.
D.	Wire-2 is moved towards right	s.	Electric field in the loop is non-zero.

Codes

	A	B	C	D		A	B	C	D
(a)	p	q	q	p	(b)	p	q	q	s
(c)	q	q	p	p	(d)	p	q	p	s

36. Match the Column I (planar loops of different shapes) with Column II (direction of induced current) and select the correct answer from the codes given below

	Column I		Column II
A.		p.	*b a c b*
B.		q.	*c d a b c*
C.		r.	*b c d a b*

Codes

	A	B	C		A	B	C
(a)	r	p	q	(b)	q	p	r
(c)	p	q	r	(d)	p	r	q

Assertion / Reasoning MCQs

*For question numbers 37 to 50, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below.*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

37. **Assertion** Magnetic flux of a magnetic field **B** passing through an area **A** is given by the relation $\phi = \mathbf{B} \cdot \mathbf{A}$.

Reason Quantity obtained by product of two vectors is always scalar.

38. **Assertion** Magnetic flux and the electric flux have the same units.

Reason Flux passing through a surface does not gives an idea about the field lines crossing that surface.

39. **Assertion** When two magnets are brought closer to each other, then they will always repel each other.

Reason According to Lenz's law induced effects do not always opposes the cause.

40. **Assertion** If a straight wire is moved in a magnetic field, no emf will be induced across its two ends as the circuit is not closed.

Reason Since, the circuit is not closed, induced current will be non-zero.

41. **Assertion** Faraday's laws are consequence of conservation of energy.

Reason Earth's magnetic field can induce emf.

42. **Assertion** Inductance coil are made of copper.

Reason Induced current is more in wire having less resistance.

43. **Assertion** Eddy currents are undersirable.

Reason Eddy currents heat up the core and dissipate electrical energy in the form of heat.

44. **Assertion** When a metallic conductor is moved in and out in a magnetic field, then an induced emf is produced across it.

Reason Eddy current will not be produced in a metallic surface moving in and out of magnetic field.

45. **Assertion** When coil in galvanometer with metallic core oscillates, then electromagnetic damping occurs.

Reason Eddy currents generated in the core opposes the motion and brings the coil to rest quickly.

46. **Assertion** Coefficient of self-induction of an inductor depends upon the rate of change of current passing through it.

Reason From $e = L\dfrac{di}{dt}$

We can see that, $L = \dfrac{e}{\left(\dfrac{di}{dt}\right)}$ or $L \propto \dfrac{1}{\left(\dfrac{di}{dt}\right)}$

47. **Assertion** The self-induced emf is also called the back emf.

Reason The self-induced emf opposes any change in the current in a circuit.

48. **Assertion** In the phenomenon of mutual induction, self-induction of each of the coils persists.

Reason Self-induction aries when strength of current in same coil changes. In mutual induction, current is changing in both the individual coils.

49. **Assertion** If the inner solenoid is much shorter than (and placed well inside) the outer solenoid, then the flux linkage $N_1\phi_1$ can still be calculated.

Reason The inner solenoid is effectively immersed in a uniform magnetic field due to the outer solenoid.

50. **Assertion** Mutual inductance of two coils does not depends on the distance between the coils and their orientation.

Reason It does not depend on the magnetic material filled between the coils.

Case Based MCQs

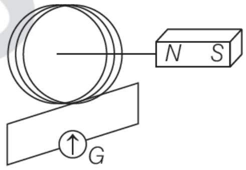
Direction *Answer the questions from 51-55 on the following case.*

Faraday's Laws

According to the Faraday's first law, whenever the amount of magnetic flux linked with a circuit changes, an emf is induced in it. Induced current is determined by the rate at which the magnetic flux changes.

Mathematically, the magnitude of the induced emf in a circuit is equal to the rate of change of magnetic flux through the circuit.

Induced emf $\propto$ Rate of change of magnetic flux



51. On the basis of Faraday's law, current in the coil is larger

(a) when the magnet is pushed towards the coil faster
(b) when the magnet is pulled away the coil faster
(c) Both (a) and (b)
(d) Neither (a) nor (b)

52. The flux linked with a circuit is given by $\phi = t^3 + 3t - 7$. The graph between time (X-axis) and induced emf (Y-axis) will be a

(a) straight line through the origin
(b) straight line with positive intercept
(c) straight line with negative intercept
(d) parabola not through the origin

53. Wire loop is rotated in a magnetic field. The frequency of change of direction of the induced emf is

(a) once per revolution
(b) twice per revolution
(c) four times per revolution
(d) six times per revolution

54. The instantaneous magnetic flux linked with a coil is given by $\phi = (5t^3 - 100t + 300)$ Wb. The emf induced in the coil at time $t = 2$ s is

(a) −40 V (b) 40 V (c) 140 V (d) 300 V

55. A copper disc of radius 0.1 m is rotated about its centre with 20 rev/s in a uniform magnetic field of 0.1 T with its plane perpendicular to the field. The emf induced across the radius of the disc is

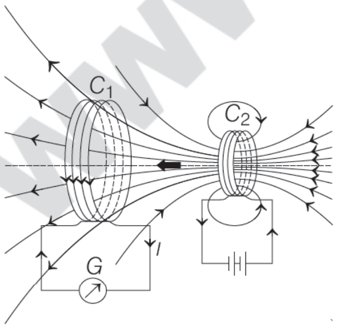
(a) $\frac{\pi}{20}$ V (b) $\frac{\pi}{10}$ V

(c) 20π mV (d) None of these

Direction *Answer the questions from 56-60 on the following case.*

Induced Current

The steady current in the coil C_2 as shown below produces a steady magnetic field. As coil C_2 is moved towards the coil C_1, the galvanometer shows a deflection. This indicates that electric current is induced in coil C_1. When C_2 is moved away, the galvanometer shows a deflection again, but this time in the opposite direction. This deflection is based upon the Faraday's law of electromagnetic induction.



56. The change in magnetic flux

(a) decreases the radius of the coil C_1 to half the initial radius
(b) induces emf in the coil C_1
(c) increases the radius of coil C_1 to double the initial radius
(d) None of the above

57. Which of the following statement(s) is/are correct?

I. The steady current in the coil C_2 produces a steady magnetic field.
II. If coil C_2 is moved towards the coil C_1, the galvanometer shows a deflection.

Choose the correct option.

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

58. What will be the direction of deflection of galvanometer, when C_2 is moved away?

(a) Same direction (b) Opposite direction
(c) No deflection (d) Neither (a) nor (b)

59. For duration of deflection in G, i.e. current flow in coil C_1, which of the following statement is correct?

(a) The deflection lasts as long as C_2 is in motion
(b) The deflection lasts till 1 min after motion of C_2 stops
(c) The deflection lasts till 1 h after motion of C_2 stops
(d) The deflection lasts forever

60. When the coil C_2 is held fixed and C_1 is moved , then

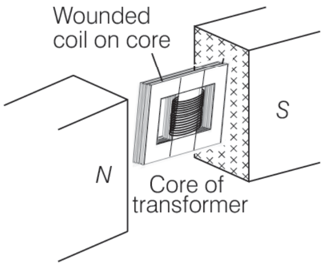
(a) same effects are observed, i.e. current is induced in coil C_1
(b) no current is induced in coil C_1
(c) number of magnetic field lines through C_1 do not change
(d) current in coil C_2 increases drastically

Direction *Answer the questions from 61-65 on the following case.*

Eddy Current

Coil is wound over metallic core is helpful in reducing eddy currents in the metallic cores of transformers, electric motors, induction furnaces and other such devices (as shown below).

Eddy currents are undesirable since they heat up the core and dissipate electrical energy in the form of heat. These currents are minimised by using laminations of metal to make a metal core.



61. Eddy currents in a metal core of transformer can be minimised

(a) by using laminations of metal
(b) by using solid metallic core
(c) Both (a) and (b)
(d) Neither (a) nor (b)

62. The plane of the laminations must be arranged parallel to the magnetic field, so that they

(a) keep on sliding
(b) keep on rotating
(c) cut across the induced eddy currents
(d) Both (a) and (b)

63. Induction furnace is used to produce

(a) low temperature to melt the metal
(b) high temperature to melt the metal
(c) constant low temperature 20°C
(d) high pressure

64. Induction furnace can be utilised to prepare

(a) alloys, by melting the constituent metals
(b) metal, by mixing electrons, protons, neutrons
(c) Both (a) and (b)
(d) Neither (a) nor (b)

65. When a high frequency alternating current is passed through a coil which surrounds the metal to be melted, then

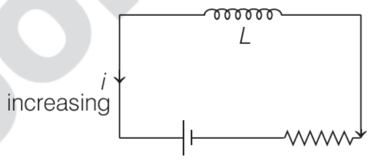
(a) the metal freezes
(b) coil rotates with frequency ω
(c) the metal melts
(d) None of the above

Direction *Answer the questions from 66-70 on the following case.*

Self-Induction

Self-induction is the property of a coil by virtue of which the coil opposes any change in the strength of current flowing through it by inducing an emf in itself.

This induced emf is also called back emf. When the current in a coil is switched ON, then the self induction opposes the growth of the current and when it is switch OFF, then the self-induction opposes the decay of the current.



66. The dimensions of self-inductance L are

(a) $[M L^0 T^{-2} A^{-2}]$
(b) $[M L^2 T^{-2} A^{-2}]$
(c) $[M^0 L^0 T^{-2} A^0]$
(d) $[M^2 L^2 T^{-2} A^{-2}]$

67. The inductor has inductance 0.54 H and carries a current that is decreasing at a uniform rate $\dfrac{di}{dt} = -0.03$ A/s, then the induced emf will be

(a) 1.2×10^{-2} V
(b) 2.2×10^{-2} V
(c) 1.62×10^{-2} V
(d) 3.2×10^{-2} V

68. In 0.2s, the current in a coil increases from 1.5 A to 2.5 A. If inductance of this coil is 60 mH, then induced current in an external resistance of $3\,\Omega$ will be

(a) 1 A
(b) 0.5 A
(c) 0.2 A
(d) 0.1 A

69. Calculate the inductance of an air core solenoid containing 300 turns, if length of solenoid is 12π cm and its cross-sectional area is 4 cm^2.

(a) 12×10^{-5} H (b) 10×10^{-5} H

(c) 20×10^{-5} H (d) 30×10^{-5} H

70. The inductance that would be needed to store 1 kWh of energy in a coil carrying a 200 A current is

(a) 100 H

(b) 150 H

(c) 180 H

(d) 200 H

ANSWERS

Multiple Choice Questions

1. (d)	*2. (c)*	*3. (a)*	*4. (c)*	*5. (d)*	*6. (a)*	*7. (a)*	*8. (b)*	*9. (d)*	*10. (c)*
11. (d)	*12. (c)*	*13. (b)*	*14. (a)*	*15. (b)*	*16. (b)*	*17. (a)*	*18. (a)*	*19. (d)*	*20. (a)*
21. (a)	*22. (a)*	*23. (c)*	*24. (c)*	*25. (d)*	*26. (a)*	*27. (c)*	*28. (d)*	*29. (b)*	*30. (b)*
31. (d)	*32. (d)*	*33. (d)*	*34. (c)*	*35. (a)*	*36. (a)*				

Assertion/Reasoning MCQs

37. (c)	*38. (d)*	*39. (d)*	*40. (d)*	*41. (c)*	*42. (a)*	*43. (a)*	*44. (c)*	*45. (a)*	*46. (d)*
47. (a)	*48. (b)*	*49. (a)*	*50 (d)*						

Case Based MCQs

51. (c)	*52. (d)*	*53. (b)*	*54. (b)*	*55. (c)*	*56. (b)*	*57. (c)*	*58. (b)*	*59. (a)*	*60. (a)*
61. (a)	*62. (c)*	*63. (b)*	*64. (a)*	*65. (c)*	*66. (b)*	*67. (c)*	*68. (d)*	*69. (a)*	*70. (c)*

SOLUTIONS

1. Dimensional formula of magnetic flux $= [ML^2T^{-2}A^{-1}]$

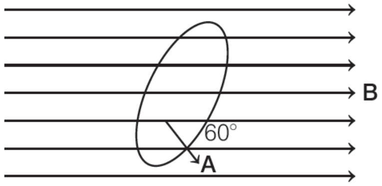
2. Given, $\mathbf{A} = L^2\hat{\mathbf{k}}$ and $\mathbf{B} = B_0(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 4\hat{\mathbf{k}})$ T

$$\therefore \quad \phi = \mathbf{B}\cdot\mathbf{A} = B_0(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 4\hat{\mathbf{k}})\cdot L^2\hat{\mathbf{k}} = 4B_0L^2 \text{ Wb}$$

3. The magnetic flux ϕ_B passing through a plane surface of area A placed in a uniform magnetic field B is given by

$$\phi_B = BA\cos\theta$$

where, θ is the angle between the direction of B and the normal (axis) to the plane.



Given, $\theta = 60°$, $B = (1/\pi)$ Wbm^{-2}

and $A = \pi(0.2)^2$

$$\therefore \quad \phi_B = \frac{1}{\pi}\times\pi(0.2)^2\times\cos 60° = (0.2)^2\times\frac{1}{2} = 0.02 \text{ Wb}$$

4. Faraday's second law states that, the magnitude of induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

It can be expressed as,

Induced emf $\propto$ Rate of change of magnetic flux

5. When the A stops moving the current in B become zero, it possible only if the current in A is constant. If the current in A would be variable, there must be an induced emf (current) in B even if the A stops moving.

6. Given, magnetic flux,

$$\phi_B = t^2 + 2$$

$$\therefore \text{Induced emf, } \varepsilon = \frac{-d\phi_B}{dt} = 2t$$

At $t = 0$, $\varepsilon = 0$

Hence, above equation is in the form of $y = mx$, so graph between t and ε will be straight line passing through origin.

7. Magnetic flux linked with the loop,

$$\phi_B = B\cdot A\cos\theta = 0.1\times(10\times10^{-2})^2\times\frac{1}{\sqrt{2}}$$

$$\phi_B = \frac{10^{-3}}{\sqrt{2}}$$

Now, induced emf in the loop,

$$e = -\frac{d\phi_B}{dt} = \frac{-\left[\frac{10^{-3}}{\sqrt{2}}\right]}{0-7} \simeq 10^{-3} \text{ V}$$

$$\therefore \text{Induced current} = \frac{e}{R} = \frac{10^{-3}}{1} = 1 \text{ mA}$$

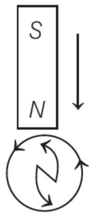
8. Lenz's law obeys the law of conservation of energy. According to it, the polarity of induced emf is such it tends to produce a current, that opposes the change in magnetic flux.

9. The induced emf will oppose the motion of the magnet. So, by applying Lenz's law, the direction of induced current will be anti-clockwise .

10. In a uniform magnetic field, change in magnetic flux is zero and due to which, induced emf is also zero. Therefore, induced current will be zero.

11. Cross $\otimes$ magnetic field passing from the closed loop is increasing, therefore from Lenz's law, induced current will produce dot$\odot$ magnetic field. Hence, induced current is anti-clockwise. So, I_1 current is flowing from b to a and I_2 current is flowing from d to c.

12. By Lenz's law, the direction of induced current in the ring is such as to oppose the falling of N-pole of the magnet.



So, the direction of induced current in the loop will be anti-clockwise because the induced current makes the ring a magnetic dipole, with its *N*-pole upward which opposes (repel) the *N*-pole of falling magnet.

13. If e is the induced emf, then according to Faraday's law $e = -\frac{d\phi}{dt} = = -Blv$

So, the potential difference between two ends of conducting rods will be Bvl.

14. Let us consider the forward motion from $x = 0$ to $x = 2b$. The flux ϕ_B linked with the circuit $SPQR$,

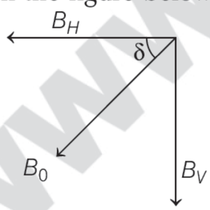
$$\phi_B = Blx, \; 0 \le x < b$$

The induced emf, $\varepsilon = -\frac{d\phi_B}{dt} = -\frac{Blx}{t}$

$$= -Blv, \; 0 \le x < b$$

This is because, both ϕ_B and ε are zero for $b < x \le 2b$, as B is zero for $x > b$.

15. The resultant magnetic field at a place is B_0 as shown in the figure below



where, δ = angle of dip,

B_H = horizontal component of earth's magnetic field and B_V = vertical component of earth's magnetic field.

When horizontal conductor of length L moves eastwards with velocity v, then it cuts vertical component of earth's magnetic field,

$\therefore \quad B_V = B_0 \sin\delta \quad \ldots(i)$

$\therefore$ Induced emf across the conductor,

$$\varepsilon = B_V vL = B_0 \sin\delta \cdot vL \quad \text{[from Eq. (i)]}$$
$$= B_0 vL \sin\delta$$

16. Induced emf, $\varepsilon_0 = \omega NBS$

$$= (2\pi\nu)\, NB(\pi r^2) = 2 \times \pi^2 \nu NBr^2$$
$$= 2 \times (3.14)^2 \times \frac{1800}{60} \times 4000 \times 0.5 \times 10^{-4} \times (7 \times 10^{-2})^2 \quad (\because 1\text{ G} = 10^{-4}\text{ T})$$
$$= 0.57 \text{ V}$$

17. When a metal is kept in continuously varying magnetic field, then magnetic flux associated with metal also continuously changes, hence eddy currents are produced in metal.

18. In induction furnace, high temperature can be produced by using eddy currents. The eddy currents generated in the metal produces high temperature to melt the metal.

19. As eddy currents show heating and magnetic effects inside the iron cores. So, here only X-ray crystallography is not based on eddy currents.

20. Inertia of mass is analogous to self-induction. Self-induction is a phenomenon in which the coil opposes any change in strength of current flowing through it by inducing an emf in itself.

21. Given, $n = 500$ turns

$$L = 50 \text{ mH} = 50 \times 10^{-3} \text{ H}$$

and $i = 8 \text{ mA} = 8 \times 10^{-3}$ A

The magnetic flux linked with the coil,

$$\phi = Li = 50 \times 10^{-3} \times 8 \times 10^{-3}$$
$$= 400 \times 10^{-6}$$
$$= 4 \times 10^{-4} \text{ Wb}$$

22. Induced emf, $e = 2$ V,

$$i_1 = 8 \text{ A}, \; i_2 = 6 \text{ A}$$

and $\Delta t = 2 \times 10^{-3}$ s

Coefficient of self-induction,

$$L = \frac{e}{\frac{\Delta i}{\Delta t}} = \frac{-2}{\frac{(6-8)}{2 \times 10^{-3}}}$$
$$= \frac{-2 \times 2 \times 10^{-3}}{-2}$$
$$= 2 \times 10^{-3} \text{ H}$$

23. Given, number of turns of solenoid,

$N = 1000$, current, $I = 4$ A

and magnetic flux, $\phi_B = 4 \times 10^{-3}$ Wb

Self-inductance of solenoid is given by

$$L = \frac{\phi_B \cdot N}{I} \quad \ldots \text{(i)}$$

Substitute the given values in Eq. (i), we get

$$L = \frac{4 \times 10^{-3} \times 1000}{4} = 1 \text{ H}$$

24. When a soft iron core is inserted in the coil, it will show self-induction effect. So, the intensity of the bulb increases.

25. Given, magnetic potential energy stored in an inductor, $U = 25$ mJ $= 25 \times 10^{-3}$ J

Current in an inductor, $I_0 = 60$ mA
$= 60 \times 10^{-3}$ A

As, the expression for energy stored in an inductor is given as

$$U = \frac{1}{2} L I_0^2$$

where, L is the inductance of the inductor.

Substituting the given values in above equation, we get

$$25 \times 10^{-3} = \frac{1}{2} \times L \times (60 \times 10^{-3})^2$$

$$\Rightarrow \quad L = \frac{2 \times 25 \times 10^{-3}}{3600 \times 10^{-6}} = \frac{500}{36}$$

or $\quad L = 13.89$ H

26. Mutual inductance between the two coils, when current is passing through coil 2,

$$M_{21} = \frac{\phi_{21}}{I_1} = \frac{\mu_0 N_1 N_2 A}{l}$$

It increases, when the distance between them decreases.

27. Mutual inductance for a co-axial solenoid of radius r_1 & r_2 and number of turns n_1 & n_2, respectively is given as

$M = \mu_0 n_1 n_2 \pi r_1^2 l$ (for internal coil of radius r_1)

Self-inductance for the internal coil,

$$L = \mu_0 n_1^2 \pi r_1^2 l$$

$$\therefore \quad \frac{M}{L} = \frac{n_1 n_2}{n_1^2} = \frac{n_2}{n_1}$$

28. Whenever the amount of magnetic flux in a circuit changes, an emf is induced in it. It is given as

$$e = \frac{-d\phi_B}{dt}$$

29. Induced emf, $e = \frac{-d\phi_B}{dt}$

But, $e = iR$ here $i = \frac{dq}{dt}$

$$\therefore \quad \frac{dq}{dt} R = \frac{-d\phi_B}{dt}$$

or $\quad dq = \frac{-d\phi_B}{R}$

So, induced charge in a coil is independent of time taken to change the flux.

30. The power required to do the work is given by

$P = \frac{B^2 l^2 v^2}{r}$, where $r =$ resistance

So, if $r \to \infty$, then $P \to 0$, i.e. power will be zero.

31. If we do not laminate the core, the current will be produced in the core which is known as eddy currents. They cause unnecessary heating and wastage of power.

32. Self-inductance of coil is directly proportional to square of number of turns in the coil, i.e.

$$L \propto N^2$$

$$\therefore \quad \frac{L_1}{L_2} = \frac{N_1^2}{N_2^2} \Rightarrow \frac{L}{L_2} = \frac{N^2}{(4N)^2}$$

$$\therefore \quad L_2 = 16L$$

33. The induced emf can be given by

$$\varepsilon = -N \frac{d\phi_B}{dt}$$

Therefore, it can be increased by increasing the number of turns N of a closed coil.

Thus, the statement given in option (d) is incorrect, rest are correct.

34. All the statements are correct but (c) is incorrect and it can be corrected as,

Eddy currents are minimised by using laminations of metal to make a metal core. The plane of laminations must be arranged parallel to the magnetic field.

35. In all of the cases, the induced current in the loop is non-zero. The direction of induced current can be determined by Lenz's law.

A. When loop is moved towards right, then according to Lenz's law, induced current in the loop is clockwise.

B. When loop is moved towards left, then according to Lenz's law, induced current in the loop is anti-clockwise.

C. Also, when wire-1 is moved towards left, then due to Lenz's law induced current will be in anti-clockwise direction.

D. When wire-2 is moved towards right, induced current will be clockwise.

Hence, A $\rightarrow$ p, B $\rightarrow$ q, C $\rightarrow$ q and D $\rightarrow$ p.

36. A. The magnetic flux through the rectangular loop *abcd* increases, due to the motion of the loop into the region of magnetic field.

Thus, the induced current must flow along the path *bcdab*, so that it opposes the increasing flux.

B. Due to the outward motion, magnetic flux through the triangular loop *abc* decreases. Thus, the induced current must flow along *bacb*, so as to oppose the change in flux.

C. As the magnetic flux decreases due to the motion of the irregular shaped loop *abcd* out of the region of magnetic field, the induced current flows along *cdabc*, so as to oppose the change in flux.

Hence, A $\rightarrow$ r, B $\rightarrow$ p and C $\rightarrow$ q.

37. Quantity obtained by product of two vectors may either be vector or scalar. Scalar product (dot product) of two vectors gives scalar quantity whereas cross product of two vectors gives vector quantity.

Since, magnetic flux of a magnetic field **B** through an area **A** is equal to scalar product $\mathbf{B} \cdot \mathbf{A}$, therefore magnetic flux is a scalar quantity.

Therefore, A is true but R is false.

38. Electric flux $= ES$ and magnetic flux $= BS$, therefore both have different units.

The total number of field lines crossing through any surface is called as flux.

Therefore, A is false and R is also false.

39. According to Lenz's law, the direction of induced emf or current in a circuit in such as to oppose the cause that produces it.

There is a force of repulsion, when two magnets of same poles are brought closer to each other.

Therefore, A is false and R is also false.

40. If a conducting rod of length l moving with a uniform velocity v perpendicular to a uniform magnetic field B, the induced emf will be $e = Bvl$.

For a closed circuit, induced current is given by $I = \frac{-d\phi}{R\,dt}$ and zero for the open circuit.

Therefore, A is false and R is also false.

41. According to Faraday's law, the conservation of mechanical energy into electrical energy is in accordance with the law of conservation of energy.

The earth's magnetic field also produces a flux through the loop. But it is a steady field and hence does not induce any emf.

Therefore, A is true but R is false.

42. Copper wire has less resistance and due to this, it has more induced current.

Also, the coil of inductance is made up of copper.

Therefore, both A and R are true and R is the correct explanation of A.

43. Eddy currents are undersirable, since they heat up the core and dissipate electrical energy in the form of heat.

Therefore, both A and R are true and R is the correct explanation of A.

44. When a metallic surface is moved in and out in a magnetic field, then magnetic flux linked with the metallic the surface is changed continuously. Hence, according to Faraday's law of elecromagnetic induction, an induced emf is produced.

Since, the metallic plate behave as a closed path, therefore an induced current (eddy current) starts flowing in the metallic surface.

Therefore, A is true but R is false.

45. Certain galvanometers have a fixed core made of non-magnetic metallic material.

When the coil oscillates, the eddy currents generated the core oppose the motion and bring the coil to rest quickly, this is called electromagnetic damping.

Therefore, both A and R are true and R is the correct explanation of A.

46. Self-inductance does not depend upon current flowing or change in current flowing but it depends upon the number of turns N, area of cross-section A and permeability of medium μ .

We have, $e = -L\dfrac{di}{dt}$

Therefore, A is false and R is also false.

47. The self-induced emf is also called the back emf, as it opposes any change in the current flowing through the circuit. Physically, the self-inductance plays the role of inertia. It is the electromagnetic analogue of mass in mechanics.

Therefore, both A and R are true and R is the correct explanation of A.

48. The total number of magnetic lines of force passing through an area placed in magnetic field equation to magnetic flux linked with the area.

Mutual inductance is the phenomenon according to which on opposing emf produces. Flux in a coil as a result of change in the current or magnetic flux linked with neighboring coil.

But when two coils are coupled, in emf produced inductively addition to induced due to mutual inductance, induced emf is also produced in each of the two coils due to self-inductance.

Therefore, both A and R are true but R is not the correct explanation of A.

49. If the inner solenoid is much shorter than (and placed well inside) the outer solenoid, then the flux linkage $N_1\phi_1$ can still be calculated.

It is because the inner solenoid is effectively immers in a uniform magnetic field due to the outer solenoid.

Therefore, both A and R are true and R is the correct explanation of A.

50. Mutual inductance of two coils depends on the distance between the coils and their orientation.

Mutual inductance depends on the magnetic permeability of medium between the coils or nature of material on which two coils are wound.

Therefore, A is false and R is also false.

51. Current will be larger, when the magnet is pushed faster towards the coil, also current is large when magnet is pulled faster away but now it is in opposite direction.

52. $\phi = t^3 + 3t - 7$

$\therefore$ Induced emf, $e = -\dfrac{d\phi}{dt}$

$$= -(3t^2 + 3) = -3t^2 - 3$$

At $t = 0$, when $e = -3$ V

The above equation is in the form of $y = -ax^2 - b$, which represents the equation of a parabola not through origin ($\because e \propto t^2$).

53. If a wire loop is rotated in a magnetic field, the frequency of change in the direction of the induced emf is twice per revolution.

54. Given, $\phi = (5t^3 - 100t + 300)$ Wb and $t = 2$ s

Induced electromotive force,

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(5t^3 - 100t + 300)$$

$$\therefore \quad e = -5\times 3t^2 + 100$$

$$= -5\times 3(2)^2 + 100 \qquad (\because t = 2\text{ s})$$

$$= -5\times 12 + 100 = -60 + 100 = 40\text{ V}$$

55. From Faraday's law of electromagnetic induction,

$$e = -\frac{d\phi}{dt} = -BAN \qquad (\because dt = 1\text{ s})$$

Given, $B = 0.1$ T

$N = 20$ rev/s and $r = 0.1$ m,

$$\therefore \quad e = 0.1\times 20\times \pi(0.1)^2 \qquad (\because A = \pi r^2)$$

$$= 20\pi\text{ mV}$$

56. According to Faraday's law of electromagnetic induction, whenever the magnetic flux associated with coil changes, then their is a induced emf in it.

So, when the magnetic flux changes, emf is induced in C_1.

57. The steady current in the coil C_2 produces a steady magnetic field.

As coil C_2 is moved towards the coil C_1, the galvanometer shows a deflection. This indicates that electric current is induced in coil C_1.

58. When C_2 is moved away, the galvanometer shows a deflection again, but this time in the opposite direction.

59. The deflection lasts as long as coil C_2 is in motion. When the coil C_2 is held fixed and coil C_1 is moved, the same effects are observed. It is the relative motion between the coils that induces the electric current. So, for the given condition, coil C_2 is in motion.

60. Galvanometer shows the deflection and same effects are observed in which the magnetic flux associated with the other coil changes.

61. Eddy currents are minimised by using laminations of metal to make a metal core.

62. The laminations are separated by an insulating material like lacquer. The plane of the laminations must be arranged parallel to the magnetic field, so that they cut across the eddy currents paths.

This arrangement reduces the strength of eddy currents. Since, the dissipation of the strength of electric current, heat loss is substantially reduced.

63. Induction furnace can be used to produce high temperatures which is utilised to prepare alloys, by melting the constituent metals. A high frequency alternating current is passed through a coil which surrounds the metals to be melted. The eddy currents generated in the metals produce high temperatures sufficient to melt it.

64. Since, induction furnaces uses the concept of eddy currents. Thus they are used to prepare alloys, by melting the constituent metals.

65. Eddy current generated in the metal leads to produce high temperature sufficient to melt it.

66. Dimensions of self-inductance L are $[\mathrm{M\,L^2\,T^{-2}A^{-2}}]$.

67. Given, inductance,

$$L = 0.54 \text{ H}$$

and $$\frac{di}{dt} = -0.03 \text{ A/s}$$

Self-induced emf is given as

$$e = -L\frac{di}{dt} = (-0.54)(-0.03) \text{ V}$$
$$= 1.62 \times 10^{-2} \text{ V}$$

68. emf induced in a coil,

$$\varepsilon = -L\frac{di}{dt}$$

Given, $L = 60 \text{ mH} = 60 \times 10^{-3}$ H

$$\Delta i = (2.5 - 1.5) \text{ A} = 1 \text{ A}$$

and $$\Delta t = 0.2 \text{ s}$$

$$\therefore \quad \varepsilon = \frac{-60 \times 10^{-3} \times 1}{0.2}$$
$$= -0.3 \text{ V}$$

Induced current,

$$i = \frac{|\varepsilon|}{R} = \frac{0.3}{3} = 0.1 \text{ A}$$

69. The inductance of a solenoid is given by

$$L = \frac{\mu_0 N^2 S}{l}$$

where, N = number of turns,

S = cross-sectional area

and l = length of solenoid.

Substituting the values, we have

$$L = \frac{(4\pi \times 10^{-7})(300)^2(4 \times 10^{-4})}{(12\pi \times 10^{-2})}$$
$$L = 12 \times 10^{-5} \text{ H}$$

70. Given, $i = 200$A

$$U = 1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

$\therefore$ Self-inductance, $L = \dfrac{2U}{i^2}$ $\quad \left(\because U = \dfrac{1}{2}Li^2\right)$

$$= \frac{2(3.6 \times 10^6)}{(200)^2}$$
$$L = 180 \text{ H}$$

07

Alternating Current

Quick Revision

1. **Alternating Current** (AC) The current whose magnitude changes continuously with time between zero and a maximum value and whose direction reverses periodically.
   The instantaneous alternating current is given by $I = I_0 \sin \omega t$, where I_0 = peak value or maximum value of AC and ω = angular frequency in rad/s.
2. **Effective Value or rms Value of AC** It is defined as that value of alternating current (AC) over a complete cycle which would generate same amount of heat in a given resistor that is generated by steady current in the same resistor and in the same time during a complete cycle. It is also called **virtual value** or **effective value** of **AC.**

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = 0.707 I_0$$

   The 70.7% value of peak value of current gives effective or rms value of AC.
3. Average or mean value of alternating current and voltage for full cycle is zero.
4. **Average or Mean Value of AC for Half Cycle** It is defined as the value of AC (Alternating Current) which would send same amount of charge through a circuit in half cycle. (i.e. $T/2$) that is sent by steady current in the same time.

$$I_{\text{av}} = \frac{2I_0}{\pi} = 0.637 I_0$$

   The 63.7% of peak value of AC gives average or mean value of AC in interval 0 to π rad.
5. **Alternating emf or Voltage** The emf, which varies in both magnitude as well as in direction alternatively and periodically. The instantaneous alternating emf is given by

$$V = V_0 \sin \omega t$$

   Hence, $V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}} = 0.707 V_0$;

$$V_{\text{av}} = \frac{2V_0}{\pi} = 0.637 V_0 \text{ (for half cycle)}$$

6. **Inductive Reactance** The opposing nature of inductor to the flow of alternating current is called inductive reactance.

$$X_L = \omega L = 2\pi f L$$

   Also for given inductor, $X_L = (2\pi L) f$
   $\Rightarrow \quad X_L \propto f \quad \because \quad 2\pi L = \text{constant}$
7. **Capacitive Reactance** The opposing nature of capacitor to the flow of alternating current is called capacitive reactance.

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

   For given capacitor, $X_C = \left(\dfrac{1}{2\pi C}\right)\dfrac{1}{f}$

$$\Rightarrow \qquad X_C \propto \frac{1}{f}$$

$$\because \qquad \frac{1}{2\pi C} = \text{constant}$$

8. **Power in an AC Circuit** $P_{av} = V_{rms} I_{rms} \cos\phi$
9. In an **AC circuit containing resistance** only,
   - Voltage and current are in same phase.
   - Maximum current, $I_0 = \dfrac{V_0}{R}$
   $$I_{rms} = \frac{V_{rms}}{R}$$
   - If $V = V_0 \sin\omega t$, then $I = I_0 \sin\omega t$.
   - Average power in R is maximum, so $P_{av} = V_{rms} I_{rms}$.
10. In an **AC circuit containing capacitor** only,
    - Capacitive reactance, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi fC}$
    - Capacitor offers infinite reactance in DC circuit, if $f = 0$ or acts as open circuit.
    - $I_0 = \dfrac{V_0}{X_C} = \dfrac{V_0}{(1/\omega C)} = V_0 \omega C$
    - Voltage lags behind the current by phase $\pi/2$.
    - If $V = V_0 \sin\omega t$, then $I = I_0 \sin\left(\omega t + \dfrac{\pi}{2}\right)$.
    - Average power consumption (during a complete cycle),
    $$P_{av} = V_{rms} I_{rms} \cos\phi = 0 \qquad \left[\because \phi = \frac{\pi}{2}\right]$$
11. In an AC **circuit containing inductor** only,
    - Inductive reactance, $X_L = \omega L = 2\pi fL$
    - Peak current, $I_0 = \dfrac{V_0}{X_L} = \dfrac{V_0}{\omega L}$
    - rms current, $I_{rms} = \dfrac{V_{rms}}{X_L} = \dfrac{V_{rms}}{\omega L}$
    - Voltage leads the current by phase $\dfrac{\pi}{2}$.
    - If $V = V_0 \sin\omega t$, then $I = I_0 \sin\left(\omega t - \dfrac{\pi}{2}\right)$.
    - Average power consumption,
    $$P_{av} = V_{rms} I_{rms} \cos\phi = 0 \qquad \left[\because \phi = \frac{\pi}{2}\right]$$
12. In ***L*-*R* series AC circuit,**
    - Impedance, $Z = \sqrt{R^2 + X_L^2} = \dfrac{V_{rms}}{I_{rms}}$
    - For the phase angle, $\tan\phi = \dfrac{X_L}{R} = \dfrac{\omega L}{R}$, voltage leads current by phase ϕ.
    - If $V = V_0 \sin\omega t$, then $I = I_0 \sin(\omega t - \phi)$.
13. In ***C*-*R* series AC circuit,**
    - Impedance, $Z = \dfrac{V_{rms}}{I_{rms}} = \sqrt{R^2 + X_C^2}$
    - For the phase angle, $\tan\phi = \dfrac{X_C}{R} = \dfrac{1}{\omega CR}$
    - If $V = V_0 \sin\omega t$, then $I = I_0 \sin(\omega t + \phi)$.
14. In an ***L*-*C* series AC circuit,**
    - Impedance, $Z = \dfrac{V_{rms}}{I_{rms}} = X_L - X_C$
    - Phase difference between voltage and current is $\pi/2$.
    - Average power, $P_{avg} = 0$
15. In an ***L*-*C*-*R* series AC circuit,**
    - Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2} = \dfrac{V_{rms}}{I_{rms}}$
    - If $X_L > X_C$, then V leads the current by phase angle ϕ and if $X_L < X_C$, then V lags behind I by phase angle ϕ, where $\tan\phi = \dfrac{X_L - X_C}{R}$.

      AC circuit is inductance dominated, if $X_L > X_C$ and capacitance dominated, if $X_C > X_L$.
16. In **resonant *L*-*C*-*R* series AC circuit,**
    - $X_L = X_C$
    - Impedance, $Z = Z_{minimum} = R$
    - The phase difference between V and I is $0°$.
    - Resonant angular frequency, $\omega_0 = \dfrac{1}{\sqrt{LC}}$
    - Average power consumption P_{av} becomes maximum.
    - Current becomes maximum and $I_{max} = \dfrac{V_{rms}}{R}$.
17. **Quality Factor** It indicates the sharpness of resonance in *L*-*C*-*R* series AC circuit.
$$Q\text{-factor} = \frac{\text{Voltage across } L \text{ or } C}{\text{Voltage across } R}$$

$$Q = \frac{V_L}{V_R} = \frac{V_C}{V_R} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

V_L, V_C and V_R are the voltages across inductor, capacitor and resistor, respectively and V is the net voltage.

18. **AC Generator** It is an electrical machine which produces electrical energy from mechanical work, just the opposite of what a motor does.

Principle An AC generator is based on the phenomenon of electromagnetic induction which states that whenever magnetic flux linked with a conductor (or coil) changes, an emf is induced in the coil.

Let magnetic flux linked with a coil,

$$\phi = BA\cos\omega t \qquad (\because \phi_0 = BA)$$

Emf induced in the coil,

$$e = -N\frac{d\phi}{dt} = -N\frac{d}{dt}BA\cos\omega t = NBA\omega\sin\omega t$$

where, N = number of turns in the coil,
B = strength of magnetic field,
A = area of each turn of the coil
and ω = angular velocity of rotation $= 2\pi f$

Hence, $e = e_0 \sin 2\pi ft \qquad [\because e_0 = NBA\omega]$

19. **Transformer** It is an electrical device which converts low alternating voltage to high alternating voltage and *vice-versa* without changing frequency of AC and power. Its working is based on the principle of mutual induction.

20. **Types of Transformer** There are two types of transformers
   - **Step-up Transformer** It converts low alternating voltage into high alternating voltage.
   - **Step-down Transformer** It converts high alternating voltage into low alternating voltage.

21. **For an ideal transformer,**

Input power = Output power

$$V_1 I_1 = V_2 I_2$$

$$\Rightarrow \frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

where, N_1 = number of turns in primary coil of the transformer and
N_2 = number of turns in secondary coil of the transformer.

Objective Questions

Multiple Choice Questions

1. Alternating current is transmitted to distant places

(a) at high voltage and low current
(b) at high voltage and high current
(c) at low voltage and low current
(d) at low voltage and high current

2. When a voltage measuring device is connected to AC mains, the meter shows the steady input voltage of 220 V. This means ***(NCERT Exemplar)***

(a) input voltage cannot be AC voltage, but a DC voltage
(b) maximum input voltage is 220 V
(c) the meter reads not V but $<V^2>$ and is calibrated to read $\sqrt{<V^2>}$
(d) the pointer of the meter is stuck by some mechanical defect

3. 220 V, 50 Hz, AC is applied to a resistor. The instantaneous value of voltage is

(a) $220\sqrt{2}\sin 100\pi t$
(b) $220\sin 100\pi t$
(c) $220\sqrt{2}\sin 50\pi t$
(d) $220\sin 50\pi t$

4. If the rms current in a 50 Hz AC circuit is 5 A, the value of the current 1/300 s after its value becomes zero is ***(NCERT Exemplar)***

(a) $5\sqrt{2}$ A (b) $5\sqrt{3/2}$ A
(c) $5/6$ A (d) $5/\sqrt{2}$ A

5. An alternating current of rms value 10 A is passed through a 12Ω resistor. The maximum potential difference across the resistor is

(a) 20 V (b) 90 V
(c) 169.7 V (d) None of these

6. Same current is flowing in two alternating circuits. The first circuit contains only inductance and the other contains only a capacitor. If the frequency of the emf of AC is increased, the effect on the value of the current

(a) increases in the first circuit and decreases in the other
(b) increases in both the circuits
(c) decreases in both the circuits
(d) decreases in the first circuit and increases in the other

7. An inductance and a resistance are connected in series with an AC potential. In this circuit

(a) the current and the potential difference across the resistance lead the PD across the inductance by phase angle $\pi/2$
(b) the current and the potential difference across the resistance lag behind PD across the inductance by an angle $\pi/2$
(c) the current and the potential difference across the resistance lag behind the PD across the inductance by an angle π
(d) the PD across the resistance lags behind the PD across the inductance by an angle $\pi/2$ but the current in the resistance leads the PD across inductance by $\pi/2$

8. An AC voltage is applied to a resistance R and an inductor L in series. If R and the inductive reactance are both equal to 3 Ω, the phase difference (in rad) between the applied voltage and the current in the circuit is

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$
(c) zero (d) $\frac{\pi}{6}$

9. In a circuit containing R and L, as the frequency of the impressed AC increases, the impedance of the circuit

(a) decreases
(b) increases
(c) remains unchanged
(d) first increases and then decreases

10. When an AC voltage is applied to an L-C-R circuit, then

(a) I and V are out of phase with each other in R
(b) I and V are in phase in L with in C, they are out of phase
(c) I and V are out of phase in both, C and L
(d) I and V are out of phase in L and in phase in C

11. In a L-C-R series circuit, the potential difference between the terminals of the inductance is 60 V, between the terminals of the capacitor is 30 V and that across the resistance is 40 V. Then, supply voltage will be equal to the

(a) 50 V (b) 70 V
(c) 130 V (d) 10 V

12. An L-C-R series circuit, connected to a source E, is at resonance. Then,

(a) the voltage across R is zero
(b) the voltage across R equals applied voltage
(c) the voltage across C is zero
(d) the voltage across C equals applied voltage

13. A sinusoidal voltage of peak value 300 V and an angular frequency $\omega = 400 \text{ rads}^{-1}$ is applied to series L-C-R circuit, in which $R = 3\Omega$, $L = 20$ mH and $C = 625\mu$F. The peak current in the circuit is

(a) $30\sqrt{2}$ A (b) 60 A
(c) 100 A (d) $60\sqrt{2}$ A

14. In an L-C-R circuit if impedance is $\sqrt{2}$ times of resistance, then find phase difference.

(a) Zero (b) 30°
(c) 60° (d) 45°

15. An L-C-R circuit contains $R = 50\ \Omega$, $L = 1$ mH and $C = 0.1\ \mu$F. The impedance of the circuit will be minimum for a frequency of

(a) $\frac{10^5}{2\pi}$ Hz (b) $\frac{10^6}{2\pi}$ Hz
(c) $2\pi \times 10^5$ Hz (d) $2\pi \times 10^6$ Hz

16. In an L-C-R series AC circuit, if ω_0 is the resonant angular frequency, then the quality factor (Q-factor) is given by

(a) $\omega_0 L/C$ (b) $(1/R)\sqrt{\frac{L}{C}}$
(c) $\omega_0 C/R$ (d) $L/\omega_0 R$

17. Which of the following combination should be selected for better tuning of an L-C-R circuit used for communication? ***(NCERT Exemplar)***

(a) $R = 20\ \Omega$, $L = 1.5$ H, $C = 35\ \mu$F
(b) $R = 25\ \Omega$, $L = 2.5$ H, $C = 45\ \mu$F
(c) $R = 15\ \Omega$, $L = 3.5$ H, $C = 30\ \mu$F
(d) $R = 25\ \Omega$, $L = 1.5$ H, $C = 45\ \mu$F

18. In an AC circuit the emf (e) and the current (i) at any instant are given respectively by,

$$e = E_0 \sin \omega t \quad \text{and} \quad i = I_0 \sin(\omega t - \phi)$$

The average power in the circuit over one cycle of AC is

(a) $\frac{E_0 I_0}{2}$ (b) $\frac{E_0 I_0}{2} \sin\phi$
(c) $\frac{E_0 I_0}{2} \cos\phi$ (d) $E_0 I_0$

19. 110 V_{rms} is applied across a series circuit having resistance 11 Ω and impedance 22 Ω. The power consumed is

(a) 275 W
(b) 366 W
(c) 550 W
(d) 1100 W

20. AC generator is used to

(a) convert low voltage into high voltage
(b) high voltage into low voltage
(c) mechanical energy into electrical energy
(d) All of the above

21. The selectivity of a series L-C-R AC circuit is large, when ***(CBSE Delhi 2020)***

(a) L is large and R is large
(b) L is small and R is small
(c) L is large and R is small
(d) $L = R$

22. The core of a transformer is laminated because

(a) energy losses due to eddy currents may be minimised
(b) the weight of the transformer may be reduced
(c) rusting of the core may be prevented
(d) ratio of voltages in primary and secondary may be increased

23. The transformation ratio in the step-up transformer is

(a) one
(b) greater than one
(c) less than one
(d) the ratio greater or less than one depends on the other factors

24. A step-up transformer operates on a 230 V line and supplies a current of 2 A. The ratio of primary and secondary windings is 1 : 25. The primary current is

(a) 12.5 A (b) 50 A (c) 8.8 A (d) 25 A

25. A transformer has 1500 turns in the primary coil and 1125 turns in the secondary coil. If the voltage in the primary coil is 200 V, then the voltage in the secondary coil is

(a) 100 V (b) 150 V (c) 200V (d) 250 V

26. The ratio of secondary to the primary turns in a transformer is 3 : 2. If the power output be P, then the input power neglecting all losses must be equal to

(a) $5P$ (b) $2P$ (c) P (d) $\left(\frac{2}{5}\right)P$

27. A transformer with turns ratio $\frac{N_1}{N_2} = \frac{50}{1}$ is connected to a 120 V AC supply. If primary and secondary circuit resistances are 1.5 kΩ and 1Ω respectively, then find out power of output.

(a) 5.76 W (b) 11.4 W (c) 2.89 W (d) 7.56 W

28. When the frequency of an AC circuit is doubled, then the capacitive reactance will be ………… .

(a) halved
(b) doubled
(c) squared
(d) Tripled

29. In an L-C-R series circuit, the voltage across each of the components L, C and R is 100 V. The voltage across the LC combination will be

(a) 0 V (b) 100 V
(c) 200 V (d) 300 V

30. In an L-C-R circuit, capacitance is changed from C to $2C$. For the resonant frequency to remain unchanged, the inductance should be changed from L to ……… .

(a) $4L$ (b) $2L$
(c) $\frac{L}{2}$ (d) $\frac{L}{4}$

31. The output of a step-down transformer is measured to be 24 V, when connected to a 12 W light bulb. The value of the peak current is ***(NCERT Exemplar)***

(a) $(1/\sqrt{2})$ A (b) $\sqrt{2}$ A
(c) 2 A (d) $2\sqrt{2}$ A

32. Which of the following statements(s) is/are incorrect with respect to tuning circuit?

(a) The antenna of a radio accepts signals from many broadcasting stations.
(b) To hear one particular radio station, radio is tuned to a particular frequency.
(c) The signals picked up in the antenna acts as a source in the tuning circuit of the radio, so the circuit can be driven at only one frequency.
(d) In tuning, we vary the capacitance of a capacitor in the tuning circuit such that the resonant frequency of the circuit becomes nearly equal to the frequency of the radio signal received.

33. Which of the following statements is/are incorrect about capacitor?

(a) The current in a capacitive circuit is $i = i_m \sin\left(\omega t - \frac{\pi}{2}\right)$.
where, the amplitude of the oscillating current is $i_m = \frac{V_m}{\omega C}$

(b) For a purely capacitive circuit $\left(\frac{1}{\omega C}\right)$ plays the role of resistance. It is called capacitive reactance and denoted by $X_C = \frac{1}{\omega C}$

(c) The current reaches its maximum value earlier than the voltage by one-fourth of a period.

(d) In case of a capacitor, the average power, $P_c = \left\langle \frac{i_m V_m}{2} \sin(2\omega t)\right\rangle = 0$
Since, $< \sin(2\omega t) > = 0$ over a complete cycle.

34. In an AC series *L-C-R* circuit, applied voltage is

$$V = \{100\sqrt{2}\sin(\omega t + 45°)\}\ \text{V}$$

Given that, $R = 30\ \Omega$, $X_L = 50\ \Omega$ and $X_C = 10\ \Omega$.

Now match the following two columns.

Column I		Column II
A. Current in the circuit	p.	120 SI units
B. Power dissipated in the circuit	q.	60 SI units
C. Potential difference across resistance	r.	2 SI units
D. Potential difference across inductance	s.	None

Codes

	A	B	C	D
(a)	p	q	r	s
(b)	r	p	q	s
(c)	p	r	s	q
(d)	q	s	r	p

35. Match the Column I (AC circuit condition) with Column II (power dissipation) and select the correct answer from the codes given below.

Column I		Column II
A. Resistive circuit	p.	No power dissipation
B. Purely inductive or capacitive circuit	q.	Maximum power dissipation because of $X_C = X_L$
C. *L-C-R* series circuit	r.	Power dissipated only in the resistor
D. Power dissipated at resonance in *L-C-R* circuit	s.	Maximum power dissipation

Codes

	A	B	C	D		A	B	C	D
(a)	p	q	s	r	(b)	s	p	r	q
(c)	r	p	s	q	(d)	q	p	r	s

Assertion/Reasoning MCQs

*For question numbers 36 to 48, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) are as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

36. **Assertion** Average value of current in half the cycle of an AC circuit cannot be zero.

Reason For positive half cycle average value of current is $\frac{i_0}{\pi}$, where i_0 is the peak value current.

37. **Assertion** The alternating current lags behind the emf by a phase angle of $\pi/2$, when AC flows through an inductor.

Reason The inductive reactance increases as the frequency of AC source decreases.

38. Assertion Inductive reactance of an inductor in DC circuit is zero.

Reason Angular frequency of DC circuit is zero.

39. Assertion If an inductor coil is connected to DC source, the current supplied by it is I_1. If the same coil is connected with an AC source of same voltage. Then, current is I_2. Then, $I_2 < I_1$.

Reason In AC circuit, inductor coil offers more resistance.

40. Assertion When the capacitor is connected to an AC source, it limits or regulates the current, but does not completely prevent the flow of charge.

Reason The capacitor is alternately charged and discharged as the current reverses each half-cycle.

41. Assertion Capacitor serves as a barrier for DC and offers an easy path to AC.

Reason Capacitive reactance is directly proportional to frequency.

42. Assertion In series, L-C-R circuit, voltage across capacitor is always less than the applied voltage.

Reason In series L-C-R circuit,

$$V = \sqrt{V^2 + (V_L + V_C)^2}$$

43. Assertion If $X_C > X_L$, ϕ is positive and the circuit is predominantly capacitive. The current in the circuit leads the source voltage.

Reason If $X_C < X_L$, ϕ is negative and the circuit is predominantly inductive. The current in the circuit lags the source voltage.

44. Assertion Resonance phenomenon is exhibited by a circuit only, if both L and C are present in the circuit.

Reason Voltage across L & C does not cancel each other and the current amplitude is V_m / R, the total source voltage appearing across R causes resonance.

45. Assertion Average power in an AC circuit is given by $P = I_{\text{rms}}^2 R$.

Reason In one full cycle, net power is dissipated not only in a resistor.

46. Assertion At resonance, power of L - C - R series circuit is zero.

Reason At resonance, $X_C > X_L$.

47. Assertion A capacitor of suitable capacitance can be used in an AC circuit in place of the choke coil.

Reason A capacitor blocks DC and allows AC only.

48. Assertion AC generator works on the principle of self induction.

Reason Magnetic flux linked with armature coil during rotation is zero always.

Case Based MCQs

Direction *Answer the questions from 49-53 on the following case.*

Electrical Resonance

Electrical resonance is said to take place in a series L-C-R circuit when the circuit allows maximum current for a given frequency of the source of alternating supply for which capacitive reactance becomes equal to the inductive reactance. Impedance of this L-C-R circuit is minimum and hence current is maximum.

Resonant circuits are used to respond selectively to signals of a given frequency while discriminating against signals of different frequencies. If the response of the circuit is more narrowly peaked around the chosen frequency, we say that the circuit has higher "selectivity or sharpness". This sharpness is measures with the help of Q-factor.

49. Bandwidth of the resonant L-C-R circuit is

(a) $\frac{R}{L}$ (b) $\frac{R}{2L}$ (c) $\frac{2R}{L}$ (d) $\frac{4R}{L}$

50. To reduce the resonant frequency in an L-C-R series circuit with a generator ***(NCERT Exemplar)***

(a) the generator frequency should be reduced
(b) another capacitor should be added in parallel to the first
(c) the iron core of the inductor should be removed
(d) dielectric in the capacitor should be removed

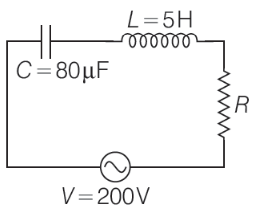
51. In a series L-C-R circuit, the capacitance C is changed to $4C$. To keep the resonant frequency same, the inductance must be changed by

(a) $2L$ (b) $L/2$
(c) $4L$ (d) $L/4$

52. In non-resonant circuit, what will be the nature of circuit for frequencies higher than the resonant frequency?

(a) Resistive (b) Capacitive
(c) Inductive (d) None of these

53. Figure shows a series L-C-R circuit, connected to a variable frequency 200 V source. $C = 80\ \mu F$ and $R = 40\ \Omega$. The source frequency which drives the circuit at resonance is

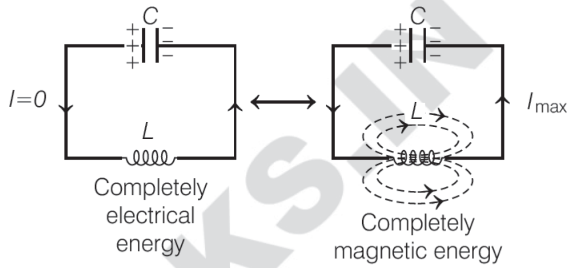


(a) 25 Hz (b) $\frac{25}{\pi}$ Hz
(c) 50 Hz (d) $\frac{50}{\pi}$ Hz

Direction *Answer the questions from 54-58 on the following case.*

L-C Oscillations

When a capacitor is supplied with an AC circuit, it gets charged.



When this charged capacitor is connected with an inductor, current flows through inductor, giving rise to magnetic flux. Hence, induced emf is produced in the circuit. Due to this, the charge on the capacitor decreases and an equivalent amount of energy is stored in the inductor in the form of magnetic field.

54. An AC circuit contains a capacitor of capacitance 10^{-6} F and an inductor of inductance 10^{-4} H. The frequency of electrical oscillations will be

(a) 10^5 Hz (b) 10 Hz
(c) $\frac{10^5}{2\pi}$ Hz (d) $\frac{10}{2\pi}$ Hz

55. The physical quantity that has same dimension as that of $\sqrt{LC}$ is

(a) length
(b) mass
(c) resistance
(d) time period

56. In an L-C circuit, angular frequency at resonance is ω. What will be the new frequency when inductor's inductance is made two times and capacitor's capacitance is made four times?

(a) $\frac{\omega}{2\sqrt{2}}$ (b) $\frac{\omega}{\sqrt{2}}$
(c) 2ω (d) $\frac{2\omega}{\sqrt{2}}$

57. The energy stored in between capacitor and inductor is given by

(a) $\frac{1}{2}LI^2$ (b) $\frac{1}{2}\frac{q^2}{C}$
(c) Both (a) and (b) (d) None of these

58. A capacitor of $1\mu F$ is charged with 0.01C of charge. The energy stored in it is

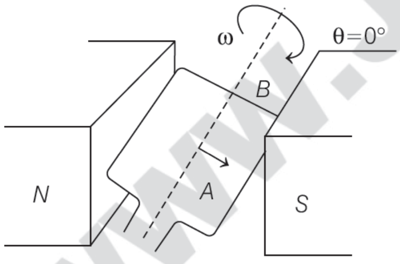
(a) 50 J (b) 100 J (c) 10 J (d) 150 J

Direction *Answer the questions from 59-63 on the following case.*

AC Generator

An AC generator produces electrical energy from mechanical work, just the opposite of what a motor does. In it, a shaft is rotated by some mechanical means, such as an engine or a turbine starts working and an emf is induced in the coil.

It is based on the phenomenon of electromagnetic induction which states that whenever magnetic flux linked with a conductor (or coil) changes, an emf is induced in the coil.



59. Which method is used to induce an emf or current in a loop in AC generator?

(a) A change in the loop's orientation
(b) A change in its effective area
(c) Both (a) and (b)
(d) Neither (a) nor (b)

60. When the coil is rotated with a constant angular speed ω, then the angle θ between the magnetic field vector **B** and the area vector **A** of the coil at any instant t, is

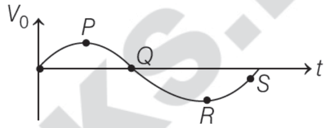
(a) $\theta = AB$ (b) $\theta = At$ (c) $\theta = \omega t$ (d) $\theta = Bt$

61. The change of flux is greatest at θ is equal to (take, $\phi_B = NBA\cos\omega t$)

(a) 90°, 270° (b) 90°, 45°
(c) 60°, 90° (d) 180°, 90°

62. The graph below shows the voltage output plotted against time.

Which point on the graph shows that the coil is in a vertical position?



(a) P (b) Q
(c) R (d) S

63. An AC generator consists of a coil of 1000 turns and cross-sectional area of 100 cm^2, rotating at an angular speed of 100 rpm in a uniform magnetic field of 3.6×10^{-2} T. The maximum emf produced in the coil is

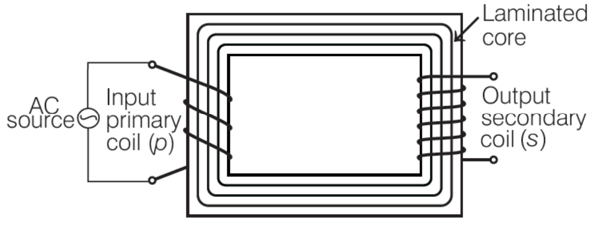
(a) 1.77 V (b) 2.77 V
(c) 3.77 V (d) 4.77 V

Direction *Answer the questions from 64-68 on the following case.*

The Transformer

Transformer is a device, which is used to increase or decrease the alternating voltage. The transformers are of the following types

(i) Step-up transformer
(ii) Step-down transformer



Transformer is based upon the principle of mutual induction. It consists of two coils, primary coil (p) and secondary coil (s), insulated from each other wounded on soft iron core.

Often the primary coil is the input coil and secondary coil is the output coil. These soft iron cores are laminated to minimise eddy current loss.

64. What is not possible in a transformer?
(a) Eddy current
(b) Direct current
(c) Alternating current
(d) Induced current

65. Which quantities do not change during transformer operation?
(a) Power
(b) Frequency
(c) Voltage
(d) Both (a) and (b)

66. A transformer has 150 turns in its primary and 1000 in secondary. If the primary is connected to 440 V DC supply, what will be the induced voltage in the secondary side?
(a) 10 V (b) 3 V
(c) 5 V (d) Zero

67. The ratio of secondary to primary turns in an ideal transformer is 4 : 5. If power input is P, then the ratio of power output to power input is
(a) 4 : 9 (b) 9 : 4
(c) 5 : 4 (d) 1 : 1

68. A power transmission line feeds input power at 2300 V to a step-down transformer with its primary windings having 4000 turns. What should be the number of turns in the secondary in order to get output power at 230 V?
(a) 600 (b) 550
(c) 400 (d) 375

ANSWERS

Multiple Choice Questions

1. (a)	2. (c)	3. (a)	4. (b)	5. (c)	6. (d)	7. (b)	8. (a)	9. (b)	10. (c)
11. (a)	12. (b)	13. (b)	14. (d)	15. (a)	16. (b)	17. (c)	18. (c)	19. (a)	20. (c)
21. (c)	22. (a)	23. (b)	24. (b)	25. (b)	26. (c)	27. (a)	28. (a)	29. (a)	30. (c)
31. (a)	32. (c)	33. (a)	34. (b)	35. (b)					

Assertion/Reasoning MCQs

36. (d)	37. (c)	38. (a)	39. (a)	40. (a)	41. (c)	42. (d)	43. (b)	44. (c)	45. (c)
46. (d)	47. (b)	48. (d)							

Case Based MCQs

49. (b)	50. (b)	51. (d)	52. (c)	53. (b)	54. (c)	55. (d)	56. (a)	57. (c)	58. (a)
59. (c)	60. (c)	61. (a)	62. (b)	63. (c)	64. (b)	65. (d)	66. (d)	67. (d)	68. (c)

SOLUTIONS

1. To prevent loss of energy as heat loss $= i^2Rt$, current (i) is kept low. Hence, alternating current is transmitted at high voltage and low current.

2. The voltmeter connected to AC mains reads mean value $(<V^2>)$ and is calibrated in such a way that it gives value of $\sqrt{<V^2>}$, which is multiplied by form factor to give rms value.

3. Here, $V_{rms} = 220\text{V}$ and $\nu = 50\,\text{Hz}$

Peak value of voltage,

$$V_0 = \sqrt{2}\,V_{rms} = 220\sqrt{2}\text{ V}$$

The instantaneous value of voltage is

$$V = V_0 \sin 2\pi\nu t$$
$$= 220\sqrt{2} \sin 2\pi \times 50t$$
$$= 220\sqrt{2} \sin 100\pi t$$

4. Given, $\nu = 50$ Hz, $I_{rms} = 5\text{A}$

$$t = \frac{1}{300}\text{ s}$$

We have to find $I(t)$

$$I_0 = \text{Peak value}$$
$$= \sqrt{2}\,I_{rms} = \sqrt{2} \times 5$$
$$= 5\sqrt{2}\text{ A}$$
$$I = I_0 \sin \omega t$$
$$= 5\sqrt{2} \sin 2\pi\nu t$$
$$= 5\sqrt{2} \sin 2\pi \times 50 \times \frac{1}{300}$$
$$= 5\sqrt{2} \sin \frac{\pi}{3}$$
$$= 5\sqrt{2} \times \frac{\sqrt{3}}{2} = 5\sqrt{3/2}\text{ A}$$

5. Maximum potential difference,

$$V_0 = I_0 R = (I_{rms}\sqrt{2})\,R$$
$$= (10\sqrt{2})(12)$$
$$= 169.7\text{ V}$$

6. $I_L = \dfrac{V}{X_L} = \dfrac{V}{\omega L}$ and $I_C = \dfrac{V}{X_C} = \omega CV$

i.e., $I_L \propto \dfrac{1}{\omega}$ and $I_C \propto \omega$

$\therefore$ With increase in ω, I_L decreases while I_C increases.

7. For a resistor, the phase difference between current and potential difference is zero. Whereas, in a pure inductor the current lags behind the voltage by $\dfrac{\pi}{2}$ radians.

Therefore, when both are connected in series, then the potential difference and current across resistor lags behind PD across the inductor by $\dfrac{\pi}{2}$.

8.

$$\tan\phi = \frac{X_L}{R} = \frac{L\omega}{R}$$
$$\Rightarrow \quad \tan\phi = \frac{3\Omega}{3\Omega}$$
$$\Rightarrow \quad \tan\phi = 1$$
$$\therefore \quad \phi = \tan^{-1}(1)$$
$$\Rightarrow \quad \phi = 45^\circ$$
$$\Rightarrow \quad \phi = \frac{\pi}{4}\text{ rad}$$

9. Impedance,

$$Z = \sqrt{R^2 + (2\pi fL)^2}$$

As f increases, Z will increase.

10. When an AC voltage is applied to an L-C-R circuit, then I and V are out of phase in both, C and L.

11. In L-C-R series circuit is given by

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$
$$= \sqrt{(40)^2 + (60-30)^2}$$
$$= \sqrt{1600 + 900}$$
$$= \sqrt{2500} = 50\text{ V}$$

12. Equation of voltage,

$$E = \sqrt{V_R^2 + (V_L - V_C)^2}$$

At resonance (series circuit),

$$V_L = V_C \Rightarrow E = V_R$$

i.e. whole applied voltage appeared across the resistance.

13. The impedance of the circuit is

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$X_L = \omega L$$
$$= 400 \times 20 \times 10^{-3} = 8\text{ H}$$

$$X_C = \frac{1}{\omega C}$$
$$= \frac{1}{400 \times 625 \times 10^{-6}} = 4\text{F}$$
$$Z = \sqrt{(3)^2 + (8-4)^2} = 5$$
$$I = \frac{E}{Z} = \frac{300}{5} = 60 \text{ A}$$

14. We know that, in series L-C-R circuit,
$$\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{2}R} = \frac{1}{\sqrt{2}} = \cos 45^\circ$$
Phase difference, $\phi = 45^\circ$

15. Impedance of L-C-R circuit will be minimum for a resonant frequency, so
$$\nu_0 = \frac{1}{2\pi\sqrt{LC}}$$
$$= \frac{1}{2\pi\sqrt{1\times10^{-3}\times 0.1\times10^{-6}}}$$
$$= \frac{10^5}{2\pi} \text{ Hz}$$

16. Quality factor, $Q = \frac{X_L}{R} = \frac{\omega_0 L}{R}$

At resonance, $\omega_0 = \frac{1}{\sqrt{LC}}$

$\therefore$ $$Q = \frac{L}{R} \times \frac{1}{\sqrt{LC}}$$
$$= \frac{1}{R}\sqrt{\frac{L}{C}}$$

17. Quality factor (Q) of an L-C-R circuit is given by
$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$
where R is resistance, L is inductance and C is capacitance of the circuit. To make Q high, R should be low, L should be high and C should be low.

These conditions are best satisfied by the values given in option (c).

18. Given, $e = E_0 \sin \omega t$ and $i = I_0 \sin(\omega t - \phi)$

Phase difference between e and $i = \phi$

$\therefore$ Average power, $P_{avg} = e_{rms} \times i_{rms} \times \cos\phi$
$$= \frac{E_0}{\sqrt{2}} \times \frac{I_0}{\sqrt{2}} \times \cos\phi$$
$$= \frac{E_0 I_0}{2}\cos\phi$$

19. $$P = V_{rms} I_{rms} \cos\phi$$
$$= V_{rms}\left(\frac{V_{rms}}{Z}\right)\left(\frac{R}{Z}\right)$$
$$= \frac{V_{rms}^2 R}{Z^2} = \frac{(110)^2 (11)}{(22)^2}$$
$$= 275 \text{ W}$$

20. AC generator is used to convert mechanical energy into electrical energy. It works on the principle of Faraday's law of electromagnetic induction.

21. A series L-C-R AC circuit is more selective, if its resonance is sharp. In this case, maximum current will be more. This implies that the circuit will have higher value of Q-factor.

As, $Q\text{-factor} = \frac{\omega_0 L}{R}$

So, for increasing it, L should be large and R should be small.

22. When magnetic flux linked with a coil changes, induced emf is produced in it and the induced current flows through the wire forming the coil.

These currents oppose the cause of their origin, therefore due to eddy currents, a great amount of energy is wasted in the form of heat energy. If core of transformer is laminated, then their effect can be minimised.

23. Transformation ratio
$$k = \frac{N_S}{N_P} = \frac{V_S}{V_P}$$
For step-up transformer,
$$N_S > N_P$$
i.e. $$V_S > V_P$$
Hence, $k > 1$.

24. As we know that, for transformer,
$$\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$$
where, all the symbols have their usual meanings. (Suffix 1 is for primary and 2 is for the secondary)
$$\Rightarrow \quad \frac{N_1}{N_2} = \frac{1}{25} = \frac{2}{I}$$
where, I = primary side current.
$$I = 50 \text{ A}$$

25. By the relation, $\frac{N_1}{N_2} = \frac{V_1}{V_2}$

Given, $N_1 = 1500$ turns,

$N_2 = 1125$ turns

and $V_1 = 200$ V

$\therefore \quad \frac{1500}{1125} = \frac{200}{V_2}$

$\Rightarrow \quad V_2 = \frac{200 \times 1125}{1500} = 150$ V

26. If the transformer is assumed to be 100% efficient (no energy losses). Then, the power input is equal to the power output.

Since, $P = IV$

$\Rightarrow \quad I_P V_P = I_S V_S$

27. Given, turn ratio of a transformer,

$$\frac{N_1}{N_2} = \frac{50}{1}$$

$\Rightarrow \quad N_1 = 50 N_2$

Since, $\frac{N_1}{N_2} = \frac{V_1}{V_2}$

$50 = \frac{120}{V_2} \qquad [V_1 = 120 \text{ V (given)}]$

$\Rightarrow \quad V_2 = \frac{12}{5}$ V

Output power at secondary coil,

$P_S = \frac{V_2^2}{R_2} \qquad [R_2 = 1\Omega \text{ (given)}]$

$= \frac{\left(\frac{12}{5}\right)^2}{1} = \frac{144}{25} = 5.76$ W

28. As capacitive reactance is,

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$$

where, ν is frequency and C is capacitance.

$\Rightarrow \quad X_C \propto \frac{1}{\nu}$

So, if frequency is doubled, then its capacitive reactance will be halved.

29. The voltage across the L-C is given by $V = V_L - V_C = 100 - 100 = 0$ V

30. At resonance $X_L = X_C$

$\Rightarrow \quad \omega = \frac{1}{\sqrt{LC}}$

Since, resonant frequency remains unchanged.

$\sqrt{LC}$ = constant

$\Rightarrow \quad L_1 C_1 = L_2 C_2$

$\Rightarrow \quad LC = L_2(2C)$

$\Rightarrow \quad L_2 = \frac{L}{2}$

31. Secondary voltage, $V_S = 24$ V

Power associated with secondary, $P_S = 12$ W

$I_S = \frac{P_S}{V_S} = \frac{12}{24}$

$= \frac{1}{2}$ A $= 0.5$ A

Peak value of the current in the secondary,

$I_0 = I_S\sqrt{2}$

$= (0.5)(1.414) = 0.707 = \frac{1}{\sqrt{2}}$ A

32. The statement given in option (c) is incorrect and it can be corrected as

The signals picked up in the antenna acts as a source in the tuning circuit of the radio, so the circuit can be driven at many frequencies. Rest statements are correct.

33. Statement given in option (a) is incorrect and it can be corrected as

The current in a capacitive circuit is

$i = i_m \sin\left(\omega t + \frac{\pi}{2}\right)$ because currents leads $\frac{\pi}{2}$ angle from voltage in capacitive circuit.

where, the amplitude of the oscillating current is

$$i_m = \frac{V_m}{X_C} = \frac{V_m}{1/\omega C} = \omega C V_m$$

Rest statements are correct.

34. As, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{30^2 + (50 - 10)^2} = 50\ \Omega$

$I = \frac{V}{Z} = \frac{100 \text{ V}}{50\ \Omega} = 2$ A

$P = I^2 R = 2^2 \times 30 = 120$ W

$V_R = IR = 2 \times 30 = 60$ V

$V_L = IX_L = 2 \times 50 = 100$ V

Hence, A $\rightarrow$ r, B $\rightarrow$ p, C $\rightarrow$ q and D $\rightarrow$ s.

35. **In Resistive circuit**

If the circuit contains only pure R, it is called resistive. In that case $\phi = 0$, $\cos\phi = 1$. There is maximum power dissipation.

In Purely inductive or capacitive circuit

If the circuit contains only an inductor or capacitor, then the phase difference between voltage and current is $\pi/2$.

Therefore, $\cos\phi = 0$ and no power is dissipated even though a current is flowing in the circuit.

In *L*-*C*-*R* series circuit

In an L-C-R series circuit, power dissipated is given by equation $P = I^2 R\cos\phi$, where $\phi = \tan^{-1}(X_C - X_L)/R$.

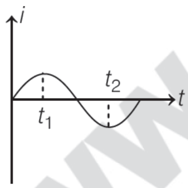
So, ϕ may be non-zero in a R-L or R-C or L-C-R circuit. Even in such cases, power is dissipated only in the resistor.

In Power dissipated at resonance in *L*-*C*-*R* circuit

At resonance, $X_C - X_L = 0$, and $\phi = 0$. Therefore, $\cos\phi = 1$ and $P = I^2 Z = I^2 R$. i.e. maximum power is dissipated in a circuit (through R) at resonance.

Therefore, A $\rightarrow$ s, B $\rightarrow$ p, C $\rightarrow$ r and D $\rightarrow$ q.

36.



In the time interval from t_1 to t_2 average value of current will be zero.

Average value of alternating current for positive half cycle

$$i_{\text{avg}} = \frac{2i_0}{\pi}$$

Therefore, A is false and R is also false.

37. The supply has voltage of $V = V_m \sin\omega t$ and the current through an inductor is

$$i = i_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

Thus, current lags behind the voltage or emf by $\pi/2$, when AC flows through an inductor.

The inductive reactance is directly proportional to the inductance and the frequency of the current as $X_L = \omega L = 2\pi\nu L$.

So, it increases as the frequency of AC source increases.

Therefore, A is true but R is false.

38. $X_L = \omega L$

In DC circuit, $f = 0$, hence $\omega = 2\pi f = 0$, $L = 0$

$\therefore \quad X_L = 0$

Therefore, both A and R are true and R is the correct explanation of A.

39.
$$Z_{\text{DC}} = r$$
$$Z_{\text{AC}} = \sqrt{r^2 + X_L^2}$$

Here, r = internal resistance of the coil.

Also, $\quad I \propto \dfrac{1}{Z}$

$\therefore \quad I_1 > I_2$

Therefore, both A and R are true and R is the correct explanation of A.

40. When the capacitor is connected to an AC source, it limits or regulates the current, but does not completely prevent the flow of charge.

It is because, the capacitor is alternately charged and discharged as the current reverses each half cycle.

Therefore, both A and R are true and R is the correct explanation of A.

41. Capacitive reactance is inversely proportional to frequency as

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

As DC does not have any frequency, i.e. $f = 0$, hence $X_C = \infty$.

So, no DC current flows through capacitor.

But AC varies like a sine function with some frequency.

So, it passes easily through capacitor.

Hence, capacitor serves as a barrier for DC and offers an easy path to AC.

Therefore, A is true but R is false.

42. $V_R \le V$, but V_C or V_L can be greater than V also.

Net voltage across series L-C-R circuit is given as $V = \sqrt{V_R^2 + (V_L - V_C)^2}$

Therefore, A is false and R is also false.

43. The phase difference between alternating current and alternating voltage in a series R-L-C circuit is $\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

So, if $X_C > X_L$, ϕ is positive and the circuit is predominantly capacitive. The current in the circuit leads the source voltage.

If $X_C < X_L$, ϕ is negative and the circuit is predominantly inductive. The current in the circuit lags the source voltage.

Therefore, both A and R are true but R is not the correct explanation of A.

44. It is important to note that resonance phenomenon is exhibited by a circuit only, if both L and C are present in the circuit.

The voltage across L and C cancel each other (both being out of phase) and the current amplitude is V_m / R. This means that we cannot have resonance in a R-L or R-C circuit,

$$V = \sqrt{V_R^2 + (V_L - V_C)^2} = V_R \quad (\because V_L = V_C)$$

Hence, the total source voltage appears across R at resonance.

Therefore, A is true but R is false.

45. $P = V_{\text{rms}}\, I_{\text{rms}} \cos\phi$

$$= (I_{\text{rms}}\, Z)\,(I_{\text{rms}})\left(\frac{R}{Z}\right) = I_{\text{rms}}^2\, R$$

As power dissipated is given by

$P = VI \cos\phi$

where, $\phi = \tan^{-1} \frac{(X_C - X_L)}{R}$

So, ϕ may be non-zero in a R-L or R-C or R-C-L circuit. Even in such cases, power is dissipated only in the resistor.

Therefore, A is true but R is false.

46. At resonance, $X_C = X_L$ and $Z = R$

$\therefore \quad \cos\phi = \frac{R}{Z} = 1$

$\therefore$ Power consumed in AC circuit

$P = V_{\text{rms}} \times I_{\text{rms}} \times \cos\phi = V_{\text{rms}} \times I_{\text{rms}}$

= maximum value.

Therefore, A is false and R is also false.

47. We can use a capacitor of suitable capacitance as a choke coil, because average power consumed per cycle in an ideal capacitor is zero. So, a condenser can reduce AC without power dissipation.

A capacitor blocks DC and allows AC only.

Therefore, both A and R are true but R is not the correct explanation of A.

48. AC generator works on the principle of Faraday's law of electromagnetic (mutual) induction. When armature coil is rotated in magnetic field, then magnetic flux linked with it is always a maximum.

Therefore, A is false and R is also false.

49. Bandwidth of resonant L-C-R circuit is $\Delta\omega = \frac{R}{2L}$.

50. We know that, resonant frequency in an L-C-R circuit is given by $\nu_0 = \frac{1}{2\pi\sqrt{LC}}$

Now, to reduce ν_0 either we can increase L or we can increase C.

To increase capacitance, we must connect another capacitor parallel to the first.

51. The resonant frequency, $f = \frac{1}{\sqrt{4\pi^2 LC}}$

$$\text{Again, } f = \frac{1}{\sqrt{4\pi^2 (L/4) \times 4C}} \Rightarrow f = \frac{1}{\sqrt{4\pi^2 LC}}$$

If the value of L is changed to $L / 4$, then the resonant frequency will remain unchanged.

52. In non-resonant circuit,

Impedance, $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$, with rise in frequency Z increases, i.e. current decrease, so circuit behaves as inductive circuit. At lower frequency $\frac{1}{\omega L} > \omega L$, the circuit becomes capacitive. At higher frequency, the circuit is inductive.

53. Resonant frequency, $\nu = \frac{1}{2\pi\sqrt{LC}}$

$$\therefore \quad = \frac{1}{2 \times 3.14 \times \sqrt{5 \times 80 \times 10^{-6}}}$$

$$= \frac{1}{2 \times 3.14 \sqrt{(400 \times 10^{-6})}}$$

$$= \frac{1}{2 \times 3.14 \times 2 \times 10^{-2}}$$

$$= \frac{100}{3.14 \times 4} = \frac{25}{3.14} = \frac{25}{\pi}\ \text{Hz}$$

54. Given, $C = 10^{-6}$F and $L = 10^{-4}$H

Resonant frequency is given by

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10^{-4} \times 10^{-6}}} = \frac{10^5}{2\pi}\text{ Hz}$$

55. Resonant frequency is given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

It can be written as,

$$\Rightarrow \quad \sqrt{LC} = \frac{1}{2\pi f}$$

$$\Rightarrow \quad \sqrt{LC} = \frac{T}{2\pi} \qquad \left[\because T = \frac{1}{f}\right]$$

Here, 2π is constant. So, dimension of $\sqrt{LC} = [M^0L^0T^1]$

56. Angular frequency at resonance,

$$\omega = \frac{1}{\sqrt{LC}}$$

According to question, new frequency is

$$\omega' = \frac{1}{\sqrt{2L \times 4C}} = \left(\frac{1}{2\sqrt{2}}\right)\frac{1}{\sqrt{LC}} = \frac{\omega}{2\sqrt{2}}$$

57. For L-C oscillator, the energy oscillates in between the capacitor and inductor as electrostatic energy and magnetic energy. It is given as

$$U = \frac{1}{2}LI^2 = \frac{1}{2}\frac{q^2}{C}$$

58. Given, capacitance, $C = 1\mu F = 10^{-6}$F

and charge, $q = 0.01\,C = 10^{-2}$C

$$\therefore \text{ Energy stored} = \frac{q^2}{2C} = \frac{(10^{-2})^2}{2 \times 10^{-6}} = 50\text{ J}$$

59. One method to induce an emf or current in a loop is through a change in the loop's orientation or a change in its effective area.

As the coil rotates in a magnetic field **B**, the effective area of the loop (the face perpendicular to the field) is $A\cos\theta$, where θ is the angle between **A** and **B**.

60. When the coil is rotated with a constant angular speed ω, the angle θ between the magnetic field vector **B** and the area vector **A** of the coil at any instant t is $\theta = \omega t$ (assuming $\theta = 0°$ at $t = 0$).

61. $\frac{d\phi_B}{dt} = -NBA\omega\sin\omega t$, change of flux is greatest for $\omega t = \theta = 90°, 270°$.

62. When the coil passes through its vertical position, its side is moving parallel to the magnetic flux between the magnetic poles, so no change of flux occurs. Hence, no emf is induced in it and output voltage is zero, i.e. at point Q.

63. Given, $N = 1000$ turns, $A = 100\text{ cm}^2 = 10^{-2}\text{ m}^2$,

$$\nu = 100\text{ rpm} = \frac{100}{60}\text{ rps}$$

and $\quad B = 3.6 \times 10^{-2}$ T

$\therefore$ Maximum emf produced in the coil is

$$e_0 = NBA\,\omega = NBA\,(2\pi\nu)$$

$$= 1000 \times 3.6 \times 10^{-2} \times 10^{-2} \times 2 \times \frac{22}{7} \times \frac{100}{60}$$

$$= 3.77\text{ V}$$

64. Transformer is used to convert the value of AC voltage. It works on the principle of mutual induction and mutual induction is not possible for direct current, so direct current is not possible in it.

65. The power and frequency do not change in a transformer operation. It changes voltage and current in a circuit.

66. As transformer works only in AC and in case of DC supply, there is no induced emf or voltage in secondary because there is no change in flux through the transformer circuit.

67. In an ideal transformer, there is no energy loss and flux is completely confined with the magnetic core, i.e. perfectly coupled.

So, $$\frac{P_{out}}{P_{in}} = 1$$

68. Here, $\varepsilon_p = 2300$ V, $N_p = 4000$, $\varepsilon_s = 230$ V

Let N_s be the required number of turns in the secondary.

As, $$\frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p} \Rightarrow N_s = N_p\left(\frac{\varepsilon_s}{\varepsilon_p}\right)$$

$$= 4000\left(\frac{230\text{ V}}{2300\text{ V}}\right) = 400$$

PRACTICE PAPER 1

Physics Class 12th (Term I)

Instructions

1. *This paper has 35 questions.*
2. *All questions are compulsory.*
3. *Each question carry 1 mark.*
4. *Answer the questions as per given instructions.*

Time : 90 Minutes **Max. Marks : 35**

Multiple Choice Questions

1. A metallic sphere is charged with induction. If the sphere is earthed again the metallic sphere becomes neutral again, it concludes conservation of

(a) mass (b) energy
(c) charge (d) momentum

2. The magnetic moment of a field with current 12 A and area 1.6 units is

(a) 19.2 (b) 12.9 (c) 21.9 (d) 91.2

3. If $\lambda = \sigma = \rho$, then the greater value of charge is on the

(a) linear charge wire
(b) charged lamina
(c) charged sphere
(d) None of the above

4. Solenoid of length 15 cm has 15000 turns carries a current of 2 A, the magnitude of magnetic induction along its axis is

(a) $2\pi \times 10^{-2}$ Wb/m^2 (b) $4\pi \times 10^{-3}$ Wb/m^2
(c) $6\pi \times 10^{-3}$ Wb/m^2 (d) $8\pi \times 10^{-3}$ Wb/m^2

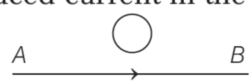
5. The coils in resistance boxes are made from doubled insultated wire to nullify the effect of

(a) heating (b) magnetism
(c) pressure (d) self-induced emf

6. In orders to achieve high accuracy, the slide wire of a potentiometer should be

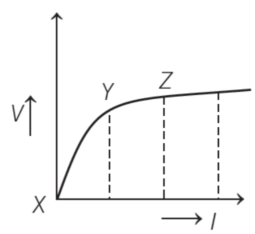
(a) as long as possible
(b) as short as possible
(c) Neither too small nor too large
(d) very thick

7. The current flows from A to B is as shown in the figure. The direction of the induced current in the loop is



(a) clockwise
(b) anti-clockwise
(c) straight line
(d) no induced emf produced

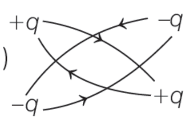
8. The graph of an active component is given below. The component can be considered ohmic for

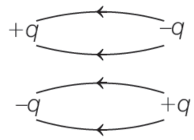


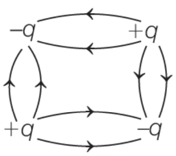
(a) XY-region
(b) YZ-region
(c) XZ-region
(d) None of the above

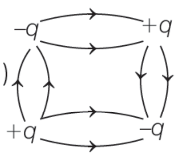
9. A magnetic quadru pole is a system of four equal charges situated at the vertices of a square having opposite polarity alternatively.

The electric field lines due to a quadrupole, is

(a) 

(b) 

(c) 

(d) 

10. The ratio of electric field due to dipole at equatorial line and axial line is

(a) 2 : 1 (b) 1 : 1
(c) 1 : 2 (d) 3 : 2

11. The vertical component of earth's magnetic field at a place is $1/\sqrt{3}$ times the horizontal component. The value of angle of dip at this place is

(a) 30° (b) 45°
(c) 60° (d) 90°

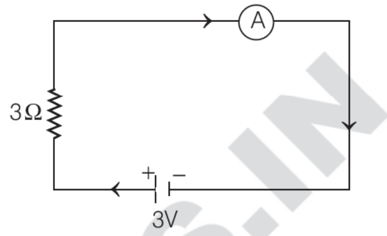
12. Two point charges of 20 μC and 80 μC are 10 cm apart. Where will the electric field strength be zero on the line joining the charges?

(a) 3.33 cm from 20 μC
(b) 3.33 cm from 20 μC
(c) 4.35 cm from 80 μC
(d) 7.33 cm from 80 μC

13. The reactance of a 25 μF capacitor at the AC frequency of 4000 Hz is

(a) $\frac{5}{\pi}\,\Omega$ (b) $\sqrt{\frac{5}{\pi}}\,\Omega$
(c) $10\,\Omega$ (d) $\sqrt{10}\,\Omega$

14. In the circuit, the current is to be measured. What is the value of current, if ammeter shown is a galvanometer with resistance $R_G = 60\ \Omega$?



(a) 21 A (b) 0.048 A
(c) 0.99 A (d) 1 A

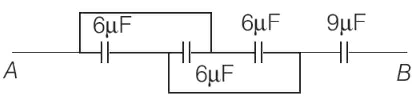
15. A point charge q is placed the centre of a cube. The electric flux linked with each face of the cube is

(a) $\frac{q}{\varepsilon_0}$ (b) $\frac{q}{6\varepsilon_0}$
(c) $\frac{q}{4\varepsilon_0}$ (d) $\frac{q}{2\varepsilon_0}$

16. If a magnet is hanged with its magnetic axis, then it stops in

(a) magnetic meridian (b) geometric meridian
(c) angle of dip (d) None of these

17. Equivalent capacitance between points A and B is

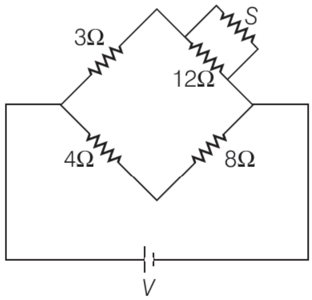


(a) 27 μF (b) 12 μF
(c) 6 μF (d) 4 μF

18. Two charges kept at a distance of 20 cm in air, attract to each other with a force of 40 N. If both charges are placed in a medium of dielectric constant 20, at same distance, then both charges will attract with a force of

(a) 40 N (b) 20 N
(c) 10 N (d) 2 N

19. For the given Wheatstone bridge, the value of S is



(a) 9 Ω (b) 6 Ω (c) 18 Ω (d) 12 Ω

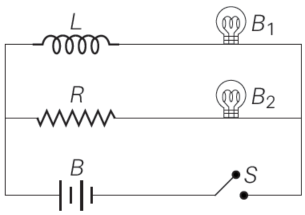
20. A proton and an α-particle, accelerated through same potential difference, enter in a region of uniform magnetic field with their velocities perpendicular to the magnetic field. The ratio of radii of circular paths followed by proton and α-particle is

(a) $1:\sqrt{2}$ (b) $1:2\sqrt{2}$
(c) 1:2 (d) 1:4

21. An infinitely long straight conductor is carrying a steady current i. The magnetic field at a distance r from the wire varies as ....

(a) $\frac{1}{\sqrt{r}}$ (b) $\frac{1}{r}$
(c) $\frac{1}{r^2}$ (d) $\frac{1}{r^3}$

22. An inductor L, a resistance R and two identical bulbs B_1 and B_2 are connected to a battery through a switch S as shown in the figure. Which of the following statements gives the correct description of the happenings, when the switch S is closed?



(a) The bulb B_2 lights up earlier than B_1 and finally both the bulbs shine equally bright.
(b) B_1 lights up earlier and finally both the bulbs acquire equal brightness.
(c) B_2 lights up earlier and finally B_1 shines brighter than B_2.
(d) B_1 and B_2 light up together with equal brightness all the time.

Assertion/Reasoning MCQs

*For question numbers 23 to 27, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

23. **Assertion** If a point charge be revolved in a circle around another charge as the centre of circle, then work done by electric field will be zero.

Reason Work done is equal to dot product of force and displacement.

24. **Assertion** The total charge stored in a capacitor is zero.

Reason The field just outside the capacitor is $\frac{\sigma}{\varepsilon_0}$, where σ is the charge density.

25. **Assertion** If a compass needle be kept at magnetic North-pole of the earth, the compass needle may stay in any direction.

Reason Dip needle will stay vertical at the North-pole of earth.

26. **Assertion** Lenz's law is in accordance with the principle of conservation of energy.

Reason Induced emf always opposes the change in magnetic flux responsible for its production.

27. **Assertion** There is no power losses associated with pure capacitances and pure inductances in AC circuit.

Reason Resistive element in AC circuit dissipates energy.

Case Based MCQs

Direction *Answer the questions from 28-31 on the following case.*

Joule's Law of Heating

An electric conductor becomes hot, when electric current is passed through it for a longer time, the heat produced in it increases as the resistance of the wire is increased, this effect is called heating effect of current or Joule's law of heating. In purely resistive circuit, the energy dissipated is entirely converted into heat energy. But if circuit contains an active component, then energy is converted into different forms. Joule's law of heating has various day-to-day purposes.

28. For a constant source of potential difference, heat produced is
(a) directly proportional to R
(b) inversely proportional to R
(c) independent of R
(d) None of the above

29. If the coil of a heater is cut in half and current supplied is kept constant, then heat produced will be
(a) doubled
(b) halved
(c) remains same
(d) becomes four times

30. The best heating element for the geyser, among all options is
(a) nichrome (b) tungsten
(c) iron (d) copper

31. The working of a fuse depends an heating effect of current. The alloy which represents fuse composition is
(a) Cu-Zn (b) Sn-Pb (c) Ag-Au (d) Fe-Ni

Direction *Answer the questions from 32-35 on the following case.*

Conductors

Whenever a conductor is placed in an external electric field, the free electrons in it experience a force due to it and start moving opposite to the field. This movement makes one side of conductor positively charged and the other as negatively charged. This creates an electric field in the conductor in a direction opposite to external electric field.

32. Under equilibrium, what is the electric field inside a conductor?
(a) Zero (b) Non-zero
(c) Infinite (d) None of these

33. What is the direction of electric field just outside the surface of conductor?
(a) Parallel (b) Perpendicular
(c) Helix (d) Both (a) and (b)

34. Conductor as a whole behaves like an
(a) equipotential
(b) dipole
(c) Both (a) and (b)
(d) None of the above

35. A highly sensitive electronic instrument can be protected from external electric fields by keeping it in a cavity of
(a) conductor
(b) insulator
(c) semiconductor
(d) None of the above

PRACTICE PAPER 1

OMRSHEET

Instructions

- Use black or blue ball point pens and avoid gel pens and fountain pens for filling the sheets
- Darken the bubbles completely. Don't put a tick mark or a cross mark half-filled or over-filled bubbles will not be read by the software.

Incorrect Incorrect Incorrect Correct

- Do not write anything on the OMR Sheet
- Multiple markings are invalid

1	a	b	c	d	19	a	b	c	d
2	a	b	c	d	20	a	b	c	d
3	a	b	c	d	21	a	b	c	d
4	a	b	c	d	22	a	b	c	d
5	a	b	c	d	23	a	b	c	d
6	a	b	c	d	24	a	b	c	d
7	a	b	c	d	25	a	b	c	d
8	a	b	c	d	26	a	b	c	d
9	a	b	c	d	27	a	b	c	d
10	a	b	c	d	28	a	b	c	d
11	a	b	c	d	29	a	b	c	d
12	a	b	c	d	30	a	b	c	d
13	a	b	c	d	31	a	b	c	d
14	a	b	c	d	Or	a	b	c	d
15	a	b	c	d	32	a	b	c	d
16	a	b	c	d	33	a	b	c	d
17	a	b	c	d	34	a	b	c	d
18	a	b	c	d	35	a	b	c	d

Students should not write anything below this line

SIGNATURE OF EXAMINER WITH DATE	MARKS SCORED

PRACTICE PAPER 2

Physics Class 12th (Term I)

Instructions

1. *This paper has 35 questions.*
2. *All questions are compulsory.*
3. *Each question carry 1 mark.*
4. *Answer the questions as per given instructions.*

Time : 90 Minutes **Max. Marks : 35**

Multiple Choice Questions

1. For a dipole, $q = 2 \times 10^{-6}$ C and $d = 0.01$ m. Calculate the maximum torque for this dipole of $E = 5 \times 10^{5}$ NC^{-1}.

(a) 1×10^{-3} Nm^{-1}
(b) 10×10^{-3} Nm^{-1}
(c) 10×10^{-3} Nm
(d) 1×10^{2} Nm^{2}

2. Assume that, electric field, $E = 30x^2 \hat{\mathbf{i}}$ exists in space. Then, the potential difference $(V_A - V_O)$, where V_O is the potential at the origin and V_A is the potential at $x = 2$ m, is

(a) 120 J (b) −120 J (c) −80 J (d) 80 J

3. In an L-C-R series circuit, the AC voltage across R, L and C come out as 10 V, 10 V and 20 V, respectively. The voltage across the entire combination will be

(a) 30 V (b) $10\sqrt{3}$ V (c) 20 V (d) $10\sqrt{2}$ V

4. Two coils X and Y are placed in a circuit such that when the current changes by 2 A in coil X. The magnetic flux changes by 0.4 Wb in Y. The value of mutual inductance of the coils is

(a) 0.2 H (b) 5 H
(c) 0.8 H (d) 4 H

5. A hot wire ammeter reads 10 A in an AC circuit. The peak value of the current will be

(a) $\frac{3}{\pi}$ A (b) $\frac{10}{\sqrt{2}}$ A (c) $10\sqrt{2}$ A (d) 6π A

6. The dimensions of mobility of charge carriers are

(a) $[M^{-2} T^{2} A]$ (b) $[M^{-1} T^{2} A]$
(c) $[M^{-2} T^{3} A]$ (d) $[M^{-1} T^{3} A]$

7. If two charges $+4e$ and $+e$ are at a distance x m apart, then at what distance charge q must be placed from $+e$, so that it is equilibrium?

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

8. A uniform electric field of 80 N/C exists along the x-axis. The potential difference $V_B - V_A$ between the points A (6m, 4m) and B (12 m, 7 m) will be

(a) 480 V (b) 240 V
(c) −480 V (d) −240 V

9. For the magnetic field to be maximum due to a small element of current carrying conductor at a point, the angle between the element and the line joining the element to the given point must be

(a) 0° (b) 90° (c) 180° (d) 45°

10. Average power in a L-C-R circuit depends upon

(a) current
(b) phase difference only
(c) emf
(d) current, emf and phase difference

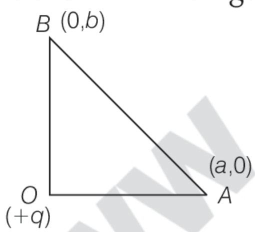
11. Gaussian surface for a line charge will be

(a) sphere (b) cuboid
(c) cube (d) cylinder

12. An electron having charge e and mass m starts from the lower plate of two metallic plates separated by a distance d. If the potential difference between the plates is V, the time taken by the electron to reach the upper plate is given by

(a) $\sqrt{\frac{2md^2}{eV}}$ (b) $\sqrt{\frac{md^2}{eV}}$ (c) $\sqrt{\frac{md^2}{2eV}}$ (d) $\frac{2md^2}{eV}$

13. A charge $+q$ is placed at the origin O of xy-axis as shown in the figure



The work done in taking a charge Q from A to B along the straight line AB is

(a) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{a-b}{ab}\right)$ (b) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{b-a}{ab}\right)$

(c) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{b}{a^2}-\frac{1}{b}\right)$ (d) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{a}{b^2}-\frac{1}{b}\right)$

14. The electric potential at a distance of 9 cm from a charge of 8 nC

(a) 270 V (b) 3 V
(c) 800 V (d) 30 V

15. In two parallel wires A and B, 10 A and 2A current respectively, is flowing in opposite directions. The distance between the wires is 10 cm. If the wire A is of infinite length and wire B is of 2m length, then the force acting on the wire B will be

(a) 8×10^{-5} N (b) 4×10^{-5} N
(c) 4×10^{-7} N (d) 8×10^{-7} N

16. The angle between magnetic meridian and geographical meridian is known as magnetic

(a) dip (b) latitude
(c) declination (d) longitude

17. A coil of resistance 400 Ω is placed in a magnetic field. If the magnetic flux ϕ_B (in Wb) linked with the coil varies with time t (in s) as, $\phi_B = 50t^2 + 4$, the value of current after 2 s is

(a) 0.5 A (b) 0.1 A
(c) 2 A (d) 1 A

18. The horizontal component of flux density of earth's magnetic field is 1.7×10^{-6} T. The value of horizontal component of intensity of earth's magnetic field will be

(a) 2.45 Am^{-1} (b) 1.35 Am^{-1}
(c) 1.53 Am^{-1} (d) 0.35 Am^{-1}

19. The capacity of a pure capacitor is 1F. In DC circuits, its effective resistance will be

(a) infinite (b) zero
(c) 1 Ω (d) $\frac{1}{2}$ Ω

20. A particle of charge q and mass m moves in a circular orbit of radius r with angular speed ω.

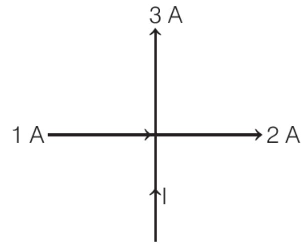
The ratio of the magnitude of its magnetic moment to that of its angular momentum is

(a) $-\frac{q}{2m}$ (b) $\frac{q\omega r^2}{2}$
(c) $\frac{q\omega}{2mr^2}$ (d) $\frac{q\omega r^2}{2m}$

21. When one electron is taken towards the other electron, then the electric potential energy of the system

(a) decreases
(b) increases
(c) remains unchanged
(d) becomes zero

22. The value of current I in figure is



(a) 4 A (b) 6A
(c) 3 A (d) 5 A

Assertion / Reasoning MCQs

*For question numbers 23 to 27, two statements are given-one labelled **Assertion** (A) and the other labelled **Reason** (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

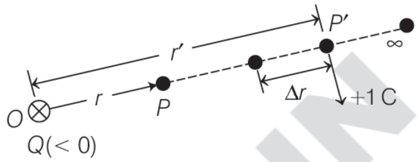
23. Assertion With the help of Gauss's theorem, we can find electric field at any point.

Reason The tempeature inside the earth is too much law.

24. Assertion The earth's magnetic field is due to iron present in its core.

Reason The temperature inside the earth is too much low.

25. Assertion Work done by the electrostatic force in bringing the unit positive charge from infinity to the point P is positive.



Reason For ($Q < 0$), the force on unit positive charge is attractive, so that the electrostatic force and the displacement (from infinity to P) are in the same direction.

26. Assertion A charged particle free to move in an electric field always moves along an electric field line.

Reason The electric field lines diverge from a negative charge and converge at a positive charge.

27. Assertion A magnetic needle which is free to swing horizontally, would lie in the magnetic meridian and the north pole of the needle would point towards the magnetic north pole.

Reason The line joining the magnetic poles is tilted with respect to the geographic axis of the earth. The magnetic meridian at a point makes some angle with the geographic meridian.

Case Based MCQs

Direction *Answer the questions from 28-31 on the following case.*

Ampere's Circuital Law

Ampere's law states that, the line integral of magnetic field, B around any closed path (Amperian loop) or circuit is equal to μ_0 times the net current crossing the area bounded by the closed path provided that the electric field inside the loop remains constant.

So, $\oint B \cdot dl = \mu_0 (i_{\text{net}})$

In this relation,we will use a sign convention given by right hand rule.

28. The Ampere's circuital law can be derived from

(a) Gauss's law (b) Newton's law
(c) Kirchhoff's law (d) Biot-Savart law

29. A straight wire carries a current of 3 A. Calculate the magnitude of the magnetic field at a point 15 cm away from the wire.

(a) 2×10^{-6} T (b) 4×10^{-6} T
(c) 8×10^{-6} T (d) 10×10^{-6} T

30. The solenoid of length 15 cm has 1500 turns carries current of 2A, the magnitude of magnetic induction at its end is

(a) $2\pi \times 10^{-3}$ Wb/m^2
(b) $4\pi \times 10^{-3}$ Wb/m^2
(c) $6\pi \times 10^{-3}$ Wb/m^2
(d) $8\pi \times 10^{-3}$ Wb/m^2

31. The relative permeability of a magnetic material depends on the

(a) flux
(b) type of magnetising force
(c) type of material
(d) None of the above

Direction *Answer the questions from 32-35 on the following case.*

Heating Effects of Current

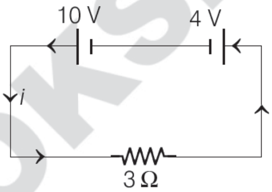
An electric current through a resistor increases its thermal energy. Also, these are other situations in which an electric current can produce or absorb thermal energy. This effect is called heating effect of electric current or Joule's law of heating effect.

When some potential difference V is applied across a resistance R and charge q to flow through the circuit in time t, the heat absorbed or produced is given by

$$W = qV = Vit = i^2 Rt$$

$$= \frac{V^2 t}{R} \text{ joule}$$

32. In the circuit shown in the following figure,



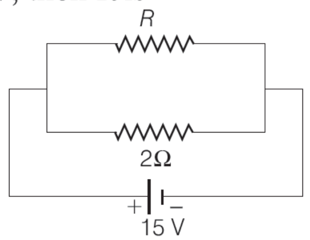
The power supplied by 10 V battery will be

(a) 10 W (b) 20 W (c) 40 W (d) 50 W

33. A television of 200 W is used for 4h, then what is the value unit expense of electricity?

(a) 50 (b) 20 (c) 0.8 (d) 0.2

34. If in the circuit, power dissipation is 150 W, then R is



(a) 2 Ω (b) 6 Ω (c) 5 Ω (d) 4 Ω

35. A and B are two bulbs connected in parallel. If A is glowing brighter than B, then the relation between R_A and R_B is

(a) $R_A = R_B$
(b) $R_B > R_A$
(c) $R_A > R_B$
(d) None of the above

PRACTICE PAPER 2

OMRSHEET

Instructions

- Use black or blue ball point pens and avoid gel pens and fountain pens for filling the sheets
- Darken the bubbles completely. Don't put a tick mark or a cross mark half-filled or over-filled bubbles will not be read by the software.

Incorrect Incorrect Incorrect Correct

- Do not write anything on the OMR Sheet
- Multiple markings are invalid

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5	a	b	c	d	23	a	b	c	d
6	a	b	c	d	24	a	b	c	d
7	a	b	c	d	25	a	b	c	d
8	a	b	c	d	26	a	b	c	d
9	a	b	c	d	27	a	b	c	d
10	a	b	c	d	28	a	b	c	d
11	a	b	c	d	29	a	b	c	d
12	a	b	c	d	30	a	b	c	d
13	a	b	c	d	31	a	b	c	d
14	a	b	c	d	Or	a	b	c	d
15	a	b	c	d	32	a	b	c	d
16	a	b	c	d	33	a	b	c	d
17	a	b	c	d	34	a	b	c	d
18	a	b	c	d	35	a	b	c	d

Students should not write anything below this line

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PRACTICE PAPER 3

Physics Class 12th (Term I)

Instructions

1. *This paper has 35 questions.*
2. *All questions are compulsory.*
3. *Each question carry 1 mark.*
4. *Answer the questions as per given instructions.*

Time : 90 Minutes **Max. Marks : 35**

Multiple Choice Questions

1. The total electric flux emanating from a closed surface enclosing an α-particle in terms of e is

(a) $\frac{2e}{\varepsilon_0}$ (b) $\frac{e}{\varepsilon_0}$ (c) $\frac{\varepsilon_0 e}{4}$ (d) $\frac{4e}{\varepsilon_0}$

2. An alternating voltage $V = 4\cos 1000t$ volt is applied to L-R circuit of inductance 3 mH and resistance $4\ \Omega$. The amplitude of current in the circuit is

(a) 8 A (b) 4 A (c) 0.8 A (d) 0.4 A

3. Two charged particles A and B having the same charge, mass and speed enter into a magnetic field in such a way that the initial path of A makes an angle of $30°$ and that of B makes an angle of $90°$ with the field. Then, the trajectory of

(a) B will have smaller radius of curvature than that of A
(b) both will have the same curvature
(c) A will have smaller radius of curvature then
(d) both will move along the direction of their original velocities

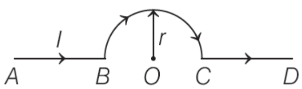
4. A water molecule has an electric dipole moment 6.4×10^{-30} C-m when it is in vapour state. The distance (in metre) between the centre of positive and negative charge of the molecule is

(a) 4×10^{-10} (b) 4×10^{-11}
(c) 4×10^{-12} (d) 4×10^{-13}

5. An inductance L a capacitance C and a resistance R may be connected to an AC source of angular frequency ω, in three different combinations of R-C, R-L and L-C in series. Assume that, $\omega L = \frac{1}{\omega C}$. The power drawn by the three combinations are P_1, P_2 and P_3, respectively. Then,

(a) $P_1 > P_2 > P_3$
(b) $P_1 = P_2 < P_3$
(c) $P_1 = P_2 > P_3$
(d) $P_1 = P_2 = P_3$

6. A long wire having a semicircular loop of radius r carries a current I, as shown below. Magnetic field due to entire wire at point O is

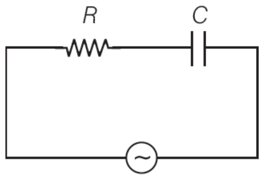


(a) $\frac{\mu_0 I}{r}$ (b) $\frac{\mu_0 I}{4r}$
(c) $\frac{3\mu_0 I}{2r}$ (d) $\frac{\mu_0 I}{2r}$

7. Current flows through a metallic conductor whose area of cross-section increases in the direction of the current. If we move in this direction, then

(a) the current will decrease
(b) the current will increase
(c) the drift velocity will increase
(d) the drift velocity will decrease

8. A 50 Hz AC source of 20 V is connected across R and C as shown in figure. The voltage across R is 12 V. The voltage across C is



(a) 8 V
(b) 16 V
(c) 10 V
(d) not possible to determine

9. A galvanometer of resistance 20 Ω gives a full scale deflection when a current of 0.04 A is passed through it. It is desired to convert into an ammeter of range 20 A. The only shunt available is 0.05 Ω. The resistance that must be connected in series with the coil of the galvanometer is

(a) 4.95 Ω
(b) 5.94 Ω
(c) 9.45 Ω
(d) 12.62 Ω

10. Two point charges exert on each other a force F when they are placed r distance apart in air. When they are placed R distance apart in a medium of dielectric constant K, they exert the same force. Then, R equals to

(a) $\frac{r}{\sqrt{K}}$ (b) $\sqrt{K}\, r$
(c) $\frac{r}{K}$ (d) Kr

11. A wire when connected to 220 V mains supply has power dissipation P_1. Now, the wire is cut into two equal pieces which are connected in parallel to the same supply. Power dissipation in this case is P_2. Then,

(a) $P_2 = 2P_1$ (b) $P_2 = 4P_1$
(c) $P_2 = \frac{P_1}{4}$ (d) $4P_2 = P_1$

12. At a point in magnetic meridian, horizontal component of earth's magnetic field is $\frac{1}{\sqrt{3}}$ times to its vertical component. Then, angle of dip at that point is

(a) 30° (b) 60°
(c) 45° (d) 90°

13. The self-inductance of a solenoid that has a cross-sectional area of 1 cm^2, a length of 10 m and 1000 turns of wire is

(a) 0.86 mH (b) 1.06 mH
(c) 1.26 mH (d) 1.46 mH

14. A parallel plate capacitor is connected to a 5 V battery and charged. The battery is then disconnected and a glass slab is introduced between the plates. Then, the quantities that decrease are

(a) charge and potential difference
(b) charge and capacitance
(c) energy and potential difference
(d) energy and capacitance

15. A charge particle of 2μC moves a distance of 10^4 m against a electric field of 100 N/C. Work done on the charge particle during this movement is

(a) 8 J (b) 200 J (c) 2 J (d) 100 J

16. An L-C circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$. At what time is the energy stored completely magnetic?

(a) $t = 0$ (b) $t = 1.57$ ms
(c) $t = 3.14$ ms (d) $t = 6.28$ ms

17. A conducting sphere of radius R is charged to a potential of V volt. Then, the electric field of a distance $(r > R)$ from the centre of the sphere would be

(a) $\frac{RV}{r^2}$ (b) $\frac{V}{r}$ (c) $\frac{rV}{R^2}$ (d) $\frac{R^2V}{r^3}$

18. The number of dry cells, each of emf 1.5 V and internal resistance 0.5 Ω that must be joined in series with a resistance of 20 Ω, so as to sent a current of 0.6 A through the circuit is

(a) 2 (b) 8 (c) 10 (d) 12

19. A wire of length 1 m is moving at a speed of 2 ms^{-1} perpendicular to its length in a homogeneous magnetic field of 0.5 T.

If the ends of the wire are joined to a circuit of resistance 6 Ω, then the rate at which work is being done to keep the wire moving at constant speed is

(a) 1 W (b) $\frac{1}{3}$ W (c) $\frac{1}{6}$ W (d) $\frac{1}{12}$ W

20. In a potentiometer of 10 wires, the balance point is obtained on the 7th wire. To shift the balance point to 9th wire, we should

(a) decrease resistance in the main circuit
(b) increase resistance in the main circuit
(c) decrease resistance in series with the cell whose emf is to be measured
(d) increase resistance in series with the cell whose emf is to be determined

21. The magnetic dipole moment of a bar magnet is a vector quantity directed

(a) from north pole to south pole
(b) from south pole to north pole
(c) perpendicular to bar magnet
(d) obliquely from bar magnet

22. The primary and secondary coils of a transformer have 50 and 1500 turns, respectively. If the magnetic flux ϕ linked with the primary coil is given by $\phi = \phi_0 + 4t$, where ϕ is in weber, t is time in second and ϕ_0 is a current, then the output voltage across the secondary coll is

(a) 90 V (b) 120 V (c) 220 V (d) 30 V

Assertion/Reasoning MCQs

For question numbers 23 to 27, two statements are given-one labelled ***Assertion*** *(A) and the other labelled* ***Reason*** *(R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.*

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

23. Assertion For a point charge, concentric spheres centered at a location of the charge are equipotential surfaces.

Reason An equipotential surface is a surface over which potential has zero value.

24. Assertion Current is passed through a metallic wire, heating it red. When cold water is poured on half of its portion, then rest of the half portion become more hot.

Reason Resistances decreases due to decrease in temperature and so current through wire increases.

25. Assertion Net magnetic flux passing through a closed surface is zero.

Reason For a closed surface, total magnetic lines of force leaving the surface is equal to total magnetic lines of force leaving the surface.

26. Assertion The quantity $\frac{L}{R}$ posseses dimensions of time.

Reason To reduce the rate of induced emf current through a solenoid should be increased.

27. **Assertion** Charge carriers do not move with acceleration but with a steady drift velocity.

Reason Charge carriers undergo collisions with ions and atoms during transit.

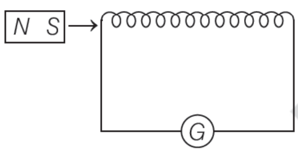
Case Based MCQs

Direction *Answer the questions from 28-31 on the following case.*

Induced emf

Ramu learnt about motional emf in his physics class. He wanted to perform Faraday's experiment. For this he made the following circuit and moved the magnet inside-out rapidly through the coil.

Although every connection he made was connected properly. But he still didn't notice any deflection in the galvanometer.



28. The deflections were noticed by Ramu because

(a) the magnets may get demagnetised
(b) the galvanometer was not sensitive enough
(c) the number of turns in the coil were less
(d) Both (b) and (c)

29. Direction of current induced in the coil can be found using

(a) Fleming's left hand rule
(b) Fleming's right hand rule
(c) Ampere's rule
(d) Right-hand clasp rule

30. A conducting rod of length l is moving in transverse magnetic field of strength B with velocity v. The resistance of the rod is R. The current in the rod is

(a) $\frac{Blv}{R}$ (b) $VBlv$ (c) zero (d) $\frac{B^2v^2l^2}{R}$

31. A bicycle generator creates 1.5 V at 15 km/hr. The emf generated at 10 km/hr is

(a) 1.5 V (b) 2 V (c) 0.5 V (d) 1 V

Direction *Answer the questions from 32-35 on the following case.*

Charging and Discharging of Capacitor

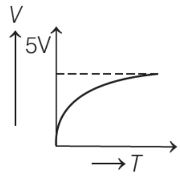
It was recently noticed that some flagship phones have two batteries of small capacity rather than one big battery. This is due to the fact that it is faster to charge two batteries completely instead of big one.

During charging, the battery can be understood as a capacitor with internal resistor r. Hence, time constant for a battery while charging and discharging is given by $\tau = RC$ where C is the capacitance. A capacitor acts as an active component which has capacitive reactance $X_C = \frac{1}{\omega C}$.

32. The unit of capacitive reactance is

(a) farad (b) ampere
(c) ohm (d) ohm^{-1}

33. The graph which correctly represents a capacitor while charging to 5 V is

(a)


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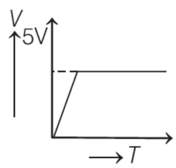
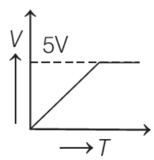
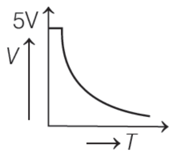


(c)


(d)


34. The capacitive reactance of 5 μF capacitor for a frequency of 10^6 Hz is

(a) 0.032 Ω (b) 2.52 Ω (c) 1.25 Ω (d) 4.51 Ω

35. In a capacitive circuit, the value of phase angle alternating current leads the emf is

(a) 45° (b) 90° (c) 75° (d) 60°

PRACTICE PAPER 3

OMRSHEET

Instructions

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Incorrect	Incorrect	Incorrect	Correct

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Or	a	b	c	d
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34	a	b	c	d
35	a	b	c	d

Students should not write anything below this line

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ANSWERS

Practice Paper 1

1. (c)	2. (a)	3. (c)	4. (d)	5. (d)	6. (a)	7. (a)	8. (a)	9. (c)	10. (c)
11. (a)	12. (b)	13. (a)	14. (b)	15. (b)	16. (a)	17. (c)	18. (d)	19. (d)	20. (a)
21. (b)	22. (c)	23. (a)	24. (c)	25. (b)	26. (a)	27. (a)	28. (b)	29. (b)	30. (a)
31. (b)	32. (a)	33. (b)	34. (a)	35. (a)					

Practice Paper 2

1. (c)	2. (c)	3. (d)	4. (a)	5. (c)	6. (b)	7. (a)	8. (c)	9. (b)	10. (d)
11. (d)	12. (a)	13. (a)	14. (c)	15. (a)	16. (c)	17. (a)	18. (b)	19. (a)	20. (a)
21. (b)	22. (a)	23. (c)	24. (d)	25. (a)	26. (d)	27. (b)	28. (d)	29. (b)	30. (b)
31. (c)	32. (b)	33. (c)	34. (b)	35. (b)					

Practice Paper 3

1. (a)	2. (c)	3. (a)	4. (b)	5. (c)	6. (b)	7. (d)	8. (b)	9. (a)	10. (a)
11. (b)	12. (b)	13. (c)	14. (c)	15. (c)	16. (b)	17. (a)	18. (c)	19. (c)	20. (d)
21. (b)	22. (b)	23. (c)	24. (a)	25. (a)	26. (c)	27. (a)	28. (d)	29. (b)	30. (a)
31. (d)	32. (c)	33. (a)	34. (a)	35. (b)					