CUET 2024 Physics Set B Question Paper with Solution

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1. In an electromagnetic wave, the ratio of energy densities of electric and magnetic fields is _______________.

Fill in the blank with the correct answer from the options given below.

(1) 1 : 1
(2) 1 : c
(3) c : 1
(4) 1 : c^2

Answer: (1) 1 : 1

Solution:

In an electromagnetic wave, the energy densities of the electric and magnetic fields are equal. This is a fundamental property of electromagnetic waves. Therefore, the ratio of their energy densities is 1:1.

> **Quick Tip**
>
> In an electromagnetic wave, the electric and magnetic fields are perpendicular to each other and their energy densities are equal.

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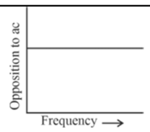
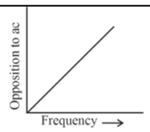
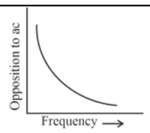
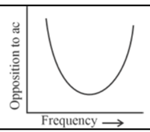
2. Match List-I has four graphs showing variation of opposition to flow of ac versus frequency with circuit characteristic in List-II.

List-I	List-II
(A) 	(I) Impedance
(B) 	(II) Capacitive reactance
(C) 	(III) Inductive reactance
(D) 	(IV) Resistance

Choose the correct answer from the options given below.

(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)
(2) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)
(3) (A) - (I), (B) - (II), (C) - (IV), (D) - (III)
(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Answer: (2) (A) - (IV), (B) - (III), (C) - (II), (D) - (I)
Solution:
Let's analyze each graph and match it with the corresponding circuit characteristic:
(A) shows a constant opposition to AC, independent of frequency. This represents **Resistance (IV)**.
(B) shows opposition increasing linearly with frequency. This is characteristic of **Inductive reactance (III)**.
(C) shows opposition decreasing hyperbolically with frequency. This behavior is seen in **Capacitive reactance (II)**.
(D) shows opposition that decreases initially and then increases. This is a combination of capacitive and inductive reactance and shows the characteristic curve of **Impedance (I)**.

Quick Tip

Understanding the frequency dependence of resistance, capacitive reactance, and inductive reactance is essential for analyzing AC circuits.

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3. Of the following, the correct arrangement of electromagnetic spectrum in decreasing order of wavelength is ____________________.
Fill in the blank with the correct answer from the options given below.
(1) Radio waves, X-rays, Infrared waves, microwaves, visible waves
(2) Infrared waves, microwaves, Radio waves, X-rays, visible waves
(3) Radio waves, microwaves, Infrared waves, visible waves, X-rays
(4) X-rays, visible waves, Infrared waves, microwaves, Radio waves

Answer: (3) Radio waves, microwaves, Infrared waves, visible waves, X-rays
Solution: The electromagnetic spectrum is arranged in decreasing order of wavelength as follows: Radio waves have the longest wavelength, followed by microwaves, infrared waves, visible light, ultraviolet light, X-rays, and finally gamma rays which have the shortest wavelength. Option (3) correctly reflects this order.

Quick Tip

Remember the order of the electromagnetic spectrum from longest to shortest wavelength: Radio, Microwave, Infrared, Visible, Ultraviolet, X-ray, Gamma.

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4. Match Electromagnetic waves listed in column I with Production method/device

in column II.

Column-I Electromagnetic waves		**Column-II Production method/device**	
(A)	Microwaves	(I)	LC oscillator
(B)	Infrared	(II)	Magnetron
(C)	X-rays	(III)	Vibration of atoms/molecules
(D)	Radio waves	(IV)	Bombarding large atomic number metal target with fast moving electrons

The correctly matched combination is as in option:
(1) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)
(2) (A) - (II), (B) - (III), (C) - (IV), (D) - (I)
(3) (A) - (II), (B) - (I), (C) - (IV), (D) - (III)
(4) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Answer: (2) (A) - (II), (B) - (III), (C) - (IV), (D) - (I)
Solution:
Microwaves are commonly produced using a **Magnetron (II)**.
Infrared radiation is produced by the **vibration of atoms/molecules (III)**.
X-rays are generated by **bombarding a large atomic number metal target with fast-moving electrons (IV)**.
Radio waves are produced using an **LC oscillator (I)**.
Therefore, the correct matching is (A) - (II), (B) - (III), (C) - (IV), (D) - (I).

Quick Tip

Understanding the mechanisms of electromagnetic wave generation is crucial for correctly matching the waves with their production methods or devices.

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5. In the figure given below, APB is a curved surface of radius of curvature 10 cm separating air and a transparent material ($\mu = 4/3$). A point object O is placed in air on the principal axis of the surface 20 cm from P. The distance of the image of O from P will be __________________.

Fill in the blank with the correct answer from the options given below.
(1) 16 cm left of P in air
(2) 16 cm right of P in water
(3) 20 cm right of P in water
(4) 20 cm left of P in air

Answer: (1) 16 cm left of P in air

Solution:

The problem involves a curved surface separating air and a transparent medium. To find the distance of the image of the object O from P, we will use the refraction formula for a spherical surface:

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

Where:

- μ_1 is the refractive index of the medium in which the object is located (air: $\mu_1 = 1$),
- μ_2 is the refractive index of the other medium (transparent material: $\mu_2 = \frac{4}{3}$),
- u is the object distance from the pole P (given: $u = -20\,\text{cm}$ since the object is on the left of the surface),
- v is the image distance from the pole P (to be found),
- R is the radius of curvature of the surface (given: $R = +10\,\text{cm}$, positive as the center of curvature lies on the right).

Substituting the values into the formula:

$$\frac{\frac{4}{3}}{v} - \frac{1}{-20} = \frac{\frac{4}{3} - 1}{10}$$

Simplify each term:

$$\frac{\frac{4}{3}}{v} + \frac{1}{20} = \frac{\frac{1}{3}}{10}$$

$$\frac{\frac{4}{3}}{v} + \frac{1}{20} = \frac{1}{30}$$

Rearranging to isolate $\frac{4}{3v}$:

$$\frac{\frac{4}{3}}{v} = \frac{1}{30} - \frac{1}{20}$$

Find the common denominator for the right-hand side:

$$\frac{1}{30} - \frac{1}{20} = \frac{2-3}{60} = -\frac{1}{60}$$

Thus:

$$\frac{\frac{4}{3}}{v} = -\frac{1}{60}$$

Multiply through by $\frac{4}{3}$ to find v:

$$\frac{1}{v} = -\frac{3}{240}$$

$$v = -80\,\text{cm}$$

The negative sign indicates that the image is on the same side as the object (left of P).

Answer: The image is formed 16 cm to the **left of P in air**.

> **Quick Tip**
>
> Carefully apply the appropriate formula for refraction at a spherical surface, paying close attention to sign conventions for object distance, image distance, and radius of curvature.

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6. For fixed values of radii of curvature of lens, power of the lens will be ____________________.

Fill in the blank with the correct answer from the options given below.

(1) $P \propto (\mu - 1)$
(2) $P \propto \mu^2$
(3) $P \propto 1/\mu$
(4) $P \propto \mu^{-2}$

Answer: (1) $P \propto (\mu - 1)$

Solution:

The lens maker's formula relates the focal length (f) of a lens to its refractive index (μ) and radii of curvature (R_1 and R_2):

$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Since the power of a lens (P) is the reciprocal of its focal length ($P = 1/f$), we can rewrite the equation as:

$P = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

For fixed values of R_1 and R_2, the term $\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ is constant. Therefore, the power of the lens is directly proportional to $(\mu - 1)$.

Thus, $P \propto (\mu - 1)$.

> **Quick Tip**
>
> The power of a lens depends on its refractive index and the radii of curvature of its surfaces. For a given lens material, the power is directly proportional to the difference between the refractive index of the lens material and the surrounding medium.

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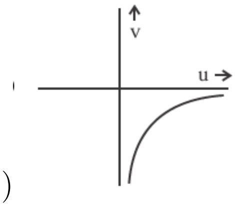
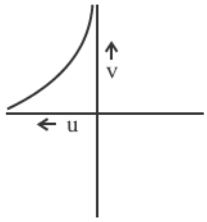
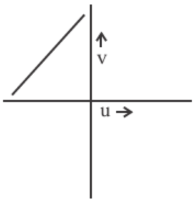
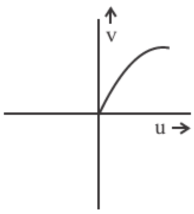
7. The graph correctly representing the variation of image distance 'v' for a convex lens of focal length 'f' versus object distance 'u' is ____________________.

Fill in the blank with the correct answer from the options given below.

(1) 

(2) 

(3) 

(4) 

Answer: (2)
Solution:
The lens formula is given by:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Where:

- v is the image distance
- u is the object distance
- f is the focal length

For a convex lens, f is positive. Rearranging the lens formula to solve for v:

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{u+f}{uf}$$
$$v = \frac{uf}{u+f}$$

As $u \to \infty$, $v \to f$. As $u \to f$, $v \to \infty$. When u is between f and $2f$, v is between $2f$ and ∞. When u is between $2f$ and ∞, v is between $2f$ and f. When $u < f$, v is negative (virtual image). This behavior is best represented by graph (2).

Quick Tip

The lens formula describes the relationship between object distance, image distance, and focal length for a lens. Sketching a graph of v versus u helps visualize the image formation process for different object positions.

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8. Using light from a monochromatic source to study diffraction in a single slit of width 0.1 mm, the linear width of central maxima is measured to be 5 mm on a screen held 50 cm away. The wavelength of light used is ____________________.
Fill in the blank with the correct answer from the options given below.
(1) $2.5 \times 10^{-7}\,\text{m}$
(2) $4 \times 10^{-7}\,\text{m}$
(3) $5 \times 10^{-7}\,\text{m}$
(4) $7.5 \times 10^{-7}\,\text{m}$

Answer: (3) 5×10^{-7} **m**
Solution:
The problem involves the diffraction of light through a single slit. The formula for the linear width of the central maximum is given by:

$$w = \frac{2\lambda D}{a}$$

Where:

- w is the linear width of the central maximum (given: $w = 5\,\text{mm} = 5 \times 10^{-3}\,\text{m}$),
- λ is the wavelength of light (to be found),
- D is the distance between the slit and the screen (given: $D = 50\,\text{cm} = 0.5\,\text{m}$),
- a is the width of the slit (given: $a = 0.1\,\text{mm} = 1 \times 10^{-4}\,\text{m}$).

Rearranging the formula to solve for λ:

$$\lambda = \frac{wa}{2D}$$

Substituting the values:

$$\lambda = \frac{(5 \times 10^{-3})(1 \times 10^{-4})}{2 \times 0.5}$$

Simplify:

$$\lambda = \frac{5 \times 10^{-7}}{1} = 5 \times 10^{-7}\,\text{m}$$

Quick Tip

In single-slit diffraction, the width of the central maximum is directly proportional to the wavelength of light and the distance to the screen and inversely proportional to the slit width.

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9. Radiation of frequency $2\nu_0$ is incident on a metal with threshold frequency ν_0. The correct statement of the following is ______________________.

Fill in the blank with the correct answer from the options given below.
(1) No photoelectrons will be emitted
(2) All photoelectrons emitted will have kinetic energy equal to $h\nu_0$
(3) Maximum kinetic energy of photoelectrons emitted can be $h\nu_0$
(4) Maximum kinetic energy of photoelectrons emitted will be $2h\nu_0$

Answer: (3) Maximum kinetic energy of photoelectrons emitted can be $h\nu_0$
Solution:
The problem is related to the photoelectric effect. The maximum kinetic energy of the photoelectrons is determined by Einstein's photoelectric equation:

$$K_{\text{max}} = hf - hf_0$$

Where:

- K_{max} is the maximum kinetic energy of the emitted photoelectrons,
- h is Planck's constant,
- f is the frequency of the incident radiation,
- f_0 is the threshold frequency of the metal.

Given:

- Frequency of incident radiation: $f = 2f_0$,
- Threshold frequency: f_0.

Substitute $f = 2f_0$ into the equation:

$$K_{\text{max}} = h(2f_0) - hf_0$$

Simplify:

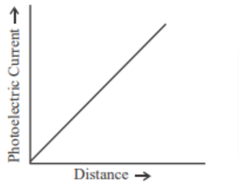
$$K_{\text{max}} = hf_0$$

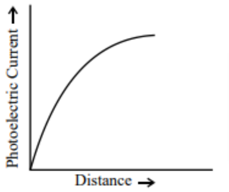
Thus, the maximum kinetic energy of the emitted photoelectrons is:

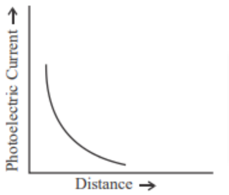
$$K_{\text{max}} = hf_0$$

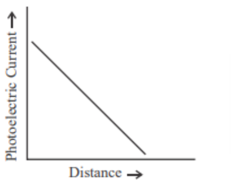
This corresponds to option (3).

10. A point source causing photoelectric emission from a metallic plate is moved away from the plate. The variation of photoelectric current with distance from the source is correctly represented by the graph ________________________.
Fill in the blank with the correct answer from the options given below.

(1) 

(2) 

(3) 

(4) 

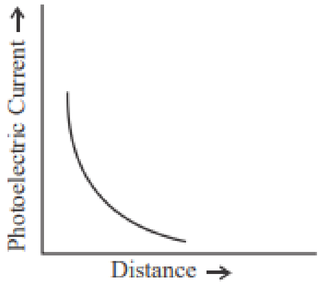
Answer: (3)
Solution:
The photoelectric current depends on the intensity of the light striking the metallic plate, and the intensity of light from a point source decreases with distance according to the inverse square law:

$$I \propto \frac{1}{d^2}$$

Where:

- I is the intensity of the light,
- d is the distance from the source.

As the intensity decreases with increasing distance, the number of photons striking the metallic plate per unit time also decreases. This results in a decrease in the photoelectric current with distance. The graph representing this relationship is a curve that asymptotically approaches zero as distance increases.

Thus, the correct graph is: 

Quick Tip

The intensity of light follows an inverse square law with distance from the source. In the photoelectric effect, the photoelectric current is directly proportional to the light intensity.

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11. A proton accelerated through a potential difference V has a de Broglie wavelength λ. On doubling the accelerating potential, de Broglie wavelength of the proton ______________________.

Fill in the blank with the correct answer from the options given below.
(1) remains unchanged
(2) becomes double
(3) becomes four times
(4) decreases

Answer: (4) decreases
Solution:
The de Broglie wavelength (λ) of a particle is given by:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$$

where:

- h is Planck's constant
- p is the momentum of the particle
- m is the mass of the particle
- K is the kinetic energy of the particle

When a proton is accelerated through a potential difference V, its kinetic energy is given by $K = qV$, where q is the charge of the proton. Therefore,

$$\lambda \propto \frac{1}{\sqrt{V}}$$

On doubling the accelerating potential (V), the kinetic energy doubles, and the momentum increases by $\sqrt{2}$. Therefore, the de Broglie wavelength decreases and becomes $\lambda/\sqrt{2}$.

Quick Tip

The de Broglie wavelength is inversely proportional to the square root of the kinetic energy (or accelerating potential) of the particle.

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12. The kinetic energy of an electron in ground level in hydrogen atom is K units. The values of its potential energy and total energy respectively are ______________________.

Fill in the blank with the correct answer from the options given below.

(1) $-2K; -K$
(2) $+2K; -K$
(3) $-K; +2K$
(4) $+K; +2K$

Answer: (1) $-2K; -K$
Solution:
For a hydrogen atom, the total energy (E) is half the potential energy (U), and the total energy is negative for a bound electron:

$$E = -\frac{K}{n^2}$$

$$U = 2E = -\frac{2K}{n^2}$$

For the ground state (n=1), the total energy is -K and the potential energy is -2K.

Quick Tip

For a hydrogen atom, the total energy is negative, and the potential energy is twice the total energy (and therefore negative).

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13. Two nuclei have mass numbers A and B respectively. The density ratio of the nuclei is ______________________.

Fill in the blank with the correct answer from the options given below.

(1) $A : B$
(2) $\sqrt{A} : \sqrt{B}$
(3) $A^2 : B^2$
(4) $1 : 1$

Answer: (4) 1 : 1
Solution:
The nuclear density is approximately constant for all nuclei, regardless of their mass number. This is because the nuclear force is short-range and nearly independent of the number of nucleons.

Quick Tip

Nuclear density is almost constant for all nuclei because the nuclear force is short-ranged and saturates.

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14. The shortest wavelengths emitted in hydrogen spectrum corresponding to different spectral series are as under:
(A) Pfund series
(B) Balmer series
(C) Brackett series
(D) Lyman series

The wavelengths arranged correctly in decreasing order are ____________________.
Fill in the blank with the correct answer from the options given below.
(1) (A), (B), (C), (D)
(2) (A), (C), (B), (D)
(3) (B), (A), (D), (C)
(4) (A), (C), (D), (B)

Answer: (4) (A), (C), (D), (B)
Solution:
The shortest wavelength corresponds to the highest energy transition in each spectral series. The order of increasing energy (and thus decreasing wavelength) for the spectral series is Pfund, Brackett, Lyman, Balmer. Therefore, the correct decreasing order of wavelengths is (A), (C), (D), (B).

Quick Tip

The energy levels in a hydrogen atom are quantized. Transitions between these energy levels produce spectral lines with specific wavelengths. Lyman series has the shortest wavelength.

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15. Silicon can be doped using one of the following elements as dopant:
(A) Arsenic
(B) Indium
(C) Phosphorus
(D) Boron

To get n-type semiconductor, the dopants that can be used are ____________________.
Fill in the blank with the correct answer from the options given below.
(1) (A) and (C) only
(2) (B) and (C) only
(3) (A), (B), (C) and (D)

(4) (C) and (D) only

Answer: (1) (A) and (C) only
Solution:
To create an n-type semiconductor, we need to introduce pentavalent (5 valence electrons) dopants into the silicon crystal lattice. Arsenic (As) and Phosphorus (P) are both pentavalent elements and are suitable dopants to create n-type semiconductors. Indium and boron are trivalent and are used for p-type semiconductors.

> **Quick Tip**
>
> N-type semiconductors are created by doping silicon with pentavalent impurities, while p-type semiconductors are created using trivalent impurities.

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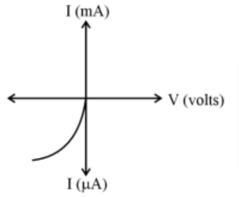
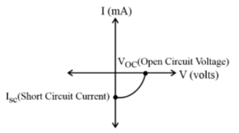
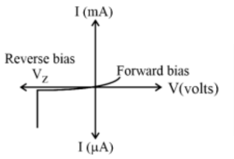
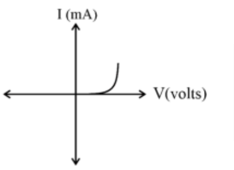
16. Given below are V versus I graphs for different types of p-n junction diodes marked A, B, C and D.

(1) 

(2) 

(3) 

(4) 

The correct sequence of graphs corresponding to forward biased p-n junction; Zener diode; Photo diode and Solar cell in order is ______________________.
Fill in the blank with the correct answer from the options given below.
(1) (D), (C), (A), (B)
(2) (A), (C), (B), (D)
(3) (B), (A), (D), (C)
(4) (C), (B), (D), (A)

Answer: (1) (D), (C), (A), (B)
Solution:

Let's analyze the I-V characteristics of each diode type:
(D) Forward biased p-n junction: Shows a typical exponential increase in current with voltage after the threshold voltage.
(C) Zener diode: Exhibits a sharp increase in current in the reverse bias region at the breakdown voltage (Vz).
(A) Photodiode: The current increases with increasing light intensity; in the dark, it shows very low reverse saturation current.
(B) Solar cell: Produces a current even in the absence of external voltage in the presence of light.
Therefore, the correct sequence is (D), (C), (A), (B).

Quick Tip

Understanding the I-V characteristics of different diode types (p-n junction, Zener, photodiode, and solar cell) is essential for identifying their behavior in circuits.

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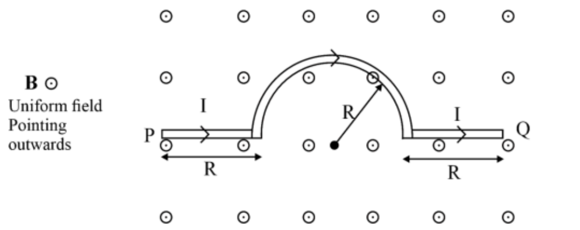
17. A wire carrying current I, bent as shown in the figure, is placed in a uniform field B that emerges normally out from the plane of the figure. The force on this wire is ______________________.



Fill in the blank with the correct answer from the options given below.
(1) $4BIR$, directed vertically downward
(2) $3BIR$, directed vertically upward
(3) $BI(2R + \pi R)$, vertically downward
(4) $2\pi BIR$, from P to Q

Answer: (3) $BI(2R + \pi R)$, vertically downward
Solution:
The force on a current-carrying wire in a magnetic field is given by $\vec{F} = I\vec{l} \times \vec{B}$, where $\vec{l}$ is the length vector of the wire segment and $\vec{B}$ is the magnetic field vector. The direction of the force is given by the right-hand rule.
The wire consists of three segments: two straight segments of length R each and a semicircular segment of radius R.
For the two straight segments, the force is given by $F_1 = I(2R)B$ directed vertically downward.
For the semicircular segment, the force is given by:

$$F_2 = \int_0^{\pi} I(Rd\theta)B \sin\theta = IRB \int_0^{\pi} \sin\theta d\theta = 2IRB$$

This force is also directed vertically downward.

The total force is the sum of the forces on the three segments:
$F = F_1 + F_2 = 2IRB + 2IRB = BI(2R + \pi R)$, vertically downward.

Quick Tip

The force on a current-carrying wire in a magnetic field is given by the cross product of the current element and the magnetic field. Remember the right-hand rule for determining the direction of the force.

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18. The refractive index of the material of an equilateral prism is $\sqrt{2}$. The angle of minimum deviation of that prism is ________________________.

Fill in the blank with the correct answer from the options given below.
(1) 60°
(2) 75°
(3) 30°
(4) 90°

Answer: (3) 30°
Solution:

The problem involves an equilateral prism with a refractive index $\mu = \sqrt{2}$. To find the angle of minimum deviation (D_{min}), we use the following relationship for a prism:

$$\mu = \frac{\sin\left(\frac{A+D_{\text{min}}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Where:

- μ is the refractive index of the material of the prism,
- A is the angle of the prism (for an equilateral prism, $A = 60^\circ$),
- D_{min} is the angle of minimum deviation.

Substitute $\mu = \sqrt{2}$ and $A = 60^\circ$ into the equation:

$$\sqrt{2} = \frac{\sin\left(\frac{60^\circ+D_{\text{min}}}{2}\right)}{\sin(30^\circ)}$$

Simplify $\sin(30^\circ)$:

$$\sqrt{2} = 2 \cdot \sin\left(\frac{60^\circ + D_{\text{min}}}{2}\right)$$

$$\sin\left(\frac{60^\circ + D_{\text{min}}}{2}\right) = \frac{\sqrt{2}}{2}$$

The angle whose sine is $\frac{\sqrt{2}}{2}$ is 45°. Therefore:

$$\frac{60^\circ + D_{\text{min}}}{2} = 45^\circ$$

Solve for D_{min}:

$$60^\circ + D_{\text{min}} = 90^\circ$$

$$D_{\text{min}} = 30^\circ$$

Quick Tip

The relationship between refractive index, prism angle, and minimum deviation angle is crucial for understanding prism behavior. Remember the formula and sign conventions.

---

19. The transfer of integral number of ______________________ is one of the evidence of quantization of electric charge.

Fill in the blank with the correct answer from the options given below.
(1) photons
(2) nuclei
(3) electrons
(4) neutrons

Answer: (3) electrons
Solution:
The quantization of electric charge is a fundamental concept in physics, stating that electric charge exists in discrete units, which are integral multiples of the elementary charge (the charge of an electron). The transfer of electrons is directly linked to the transfer of charge in integral multiples of e, providing direct evidence of charge quantization.

Quick Tip

Quantization of electric charge means that electric charge exists in discrete units, and it is an integral multiple of the elementary charge (e).

---

20. When a slab of insulating material 4 mm thick is introduced between the plates of a parallel plate capacitor of separation 4 mm, it is found that the distance between the plates has to be increased by 3.2 mm to restore the capacity to its original value. The dielectric constant of the material is ______________________.

Fill in the blank with the correct answer from the options given below.
(1) 2
(2) 5

(3) 3
(4) 7

Answer: (2) 5
Solution:
The capacitance of a parallel plate capacitor is given by:

$$C = \frac{\epsilon_0 A}{d}$$

where:

- C is the capacitance
- ϵ_0 is the permittivity of free space
- A is the area of the plates
- d is the distance between the plates

When a dielectric material of thickness t and dielectric constant K is introduced between the plates, the capacitance becomes:

$$C' = \frac{K\epsilon_0 A}{d - t + t/K}$$

If the capacitance remains the same after introducing the dielectric, then $C = C'$, thus:

$$\frac{\epsilon_0 A}{d} = \frac{K\epsilon_0 A}{d - t + t/K}$$

$$d = K(d - t + t/K) = Kd - Kt + t$$

$$K = \frac{d}{d - t + t/K} = \frac{4}{4 - 4 + 4/K} = \frac{4}{4/K} = K$$

$$K(d - t) = d - t$$

$$K = \frac{d}{d - t} = \frac{4}{4 - 4 + 3.2} = \frac{4}{0.8} = 5$$

Quick Tip

Introducing a dielectric material between the plates of a capacitor increases its capacitance by a factor equal to the dielectric constant.

---

21. A copper ball of density $8.0\,\mathrm{g/cc}$ and $1\,\mathrm{cm}$ in diameter is immersed in oil of density $0.8\,\mathrm{g/cc}$. The charge on the ball if it remains just suspended in oil in an electric field of intensity $600 \times 10^3\,\mathrm{V/m}$ acting in the upward direction is ________________________. (Take $g = 10\,\mathrm{m/s^2}$)
Fill in the blank with the correct answer from the options given below.

(1) 2×10^{-6} C
(2) 2×10^{-5} C
(3) 1×10^{-5} C
(4) 1×10^{-6} C

Answer: (1) 2×10^{-6} C
Solution:
For the copper ball to be suspended, the upward electric force must balance the downward gravitational force.
Upward electric force $F_e = qE$, where q is the charge and E is the electric field intensity.
Downward gravitational force $F_g = mg = V\rho g$, where V is the volume, ρ is the density, and g is the acceleration due to gravity.
The volume of the copper ball is given by:

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(0.5)^3 = \frac{\pi}{6}\text{ cm}^3$$

$$V = \frac{\pi}{6} \times 10^{-6}\text{ m}^3$$

Equating the forces:

$$qE = V(\rho - \rho_{oil})g$$

$$q = \frac{V(\rho - \rho_{oil})g}{E} = \frac{(\pi/6) \times 10^{-6}(8 - 0.8) \times 10}{600 \times 10^3} = \frac{(\pi/6) \times 10^{-6} \times 7.2 \times 10}{600 \times 10^3} \approx 2 \times 10^{-6}\text{ C}$$

Quick Tip

When a charged object is suspended in a fluid in an electric field, the electric force must balance the buoyant force and the gravitational force.

---

22. A metal wire is subjected to a constant potential difference. When the temperature of the metal wire increases, the drift velocity of the electron in it _______________________.
Fill in the blank with the correct answer from the options given below.
(1) increases, thermal velocity of the electrons decreases
(2) decreases, thermal velocity of the electrons decreases
(3) increases, thermal velocity of the electrons increases
(4) decreases, thermal velocity of the electrons increases

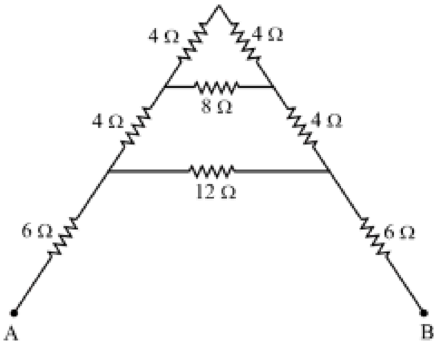
Answer: (4) decreases, thermal velocity of the electrons increases
Solution:
The drift velocity of electrons is inversely proportional to the collision time and directly proportional to the electric field. When the temperature increases, the thermal velocity of electrons increases leading to an increase in the number of collisions. This increases the resistance, which causes the drift velocity to decrease.

Quick Tip

Drift velocity is the average velocity of electrons in a conductor under the influence of an electric field. Thermal velocity is the random velocity due to temperature. Increased temperature increases the thermal velocity, reducing drift velocity.

---

23. For the given mixed combination of resistors calculate the total resistance between points A and B.



Choose the correct answer from the options given below.

(1) 9 Ω
(2) 18 Ω
(3) 4 Ω
(4) 14 Ω

Answer: (3) 4 Ω

Solution:

This requires solving a Wheatstone bridge. The bridge is balanced because:

$\frac{4}{4} = \frac{4}{4}$

Therefore, the 8 Ω resistor is irrelevant, and the circuit simplifies to:

$R_{total} = \frac{(4+4)(6+6)}{4+4+6+6} = \frac{8\times12}{20} = \frac{96}{20} = 4.8\,\Omega$

Quick Tip

In a balanced Wheatstone bridge, the central resistor has no effect on the total resistance.

---

24. A cell of emf 1.1 V and internal resistance 0.5 Ω is connected to a wire of resistance 0.5 Ω. Another cell of the same emf is now connected in series with the intention of increasing the current but the current in the wire remains the same. The internal resistance of the second cell is ______________________.

Fill in the blank with the correct answer from the options given below.

(1) 1 Ω
(2) 2.5 Ω
(3) 1.5 Ω

(4) 2 Ω

Answer: (1) 1 Ω
Solution:

The problem involves two cells of identical EMF connected in series with a resistor. The current in the circuit remains unchanged when the second cell is added. Let us calculate the internal resistance of the second cell.

Given Data:

- EMF of each cell: $E = 1.1\,\text{V}$,
- Internal resistance of the first cell: $r_1 = 0.5\,\Omega$,
- Resistance of the external wire: $R = 0.5\,\Omega$,
- Internal resistance of the second cell: r_2 (to be found),
- Current in the circuit remains the same.

Initial Circuit: When only the first cell is connected, the total resistance in the circuit is:

$$R_{\text{total, initial}} = r_1 + R = 0.5 + 0.5 = 1\,\Omega$$

The current in the circuit is:

$$I = \frac{E}{R_{\text{total, initial}}} = \frac{1.1}{1} = 1.1\,\text{A}$$

Modified Circuit: When the second cell is added in series, the total EMF becomes:

$$E_{\text{total}} = E + E = 2.2\,\text{V}$$

The total resistance of the circuit is:

$$R_{\text{total, final}} = r_1 + r_2 + R$$

Since the current remains unchanged, we equate the currents for both configurations:

$$\frac{E_{\text{total}}}{R_{\text{total, final}}} = \frac{E}{R_{\text{total, initial}}}$$

Substitute the values:

$$\frac{2.2}{r_1 + r_2 + R} = \frac{1.1}{1}$$

Simplify:

$$\frac{2.2}{0.5 + r_2 + 0.5} = 1.1$$

$$\frac{2.2}{1 + r_2} = 1.1$$

Cross-multiply:

$$2.2 = 1.1(1 + r_2)$$

$$2.2 = 1.1 + 1.1r_2$$

$$1.1 = 1.1r_2$$

$$r_2 = 1\,\Omega$$

Quick Tip

Kirchhoff's laws are essential for analyzing circuits with multiple voltage sources and resistors. Remember to consider both the emf and internal resistance of cells.

---

25. P, Q, R and S are four wires of resistances 3, 3, 3 and 4 Ω respectively. They are connected to form the four arms of a wheatstone bridge circuit. The resistance with which S must be shunted in order that the bridge may be balanced is ______________________.

Fill in the blank with the correct answer from the options given below.

(1) 14 Ω

(2) 12 Ω

(3) 15 Ω

(4) 7 Ω

Answer: (2) 12 Ω

Solution:

The problem involves a Wheatstone bridge circuit with resistances P, Q, R, and S of values $3\,\Omega$, $3\,\Omega$, $3\,\Omega$, and $4\,\Omega$, respectively. To balance the bridge, S must be shunted with a resistor of appropriate value.

Balancing Condition for a Wheatstone Bridge:

The Wheatstone bridge is balanced when:

$$\frac{P}{Q} = \frac{R}{S_{\text{eff}}}$$

Where:

- $P = 3\,\Omega$,
- $Q = 3\,\Omega$,
- $R = 3\,\Omega$,
- S_{eff} is the effective resistance of S after it is shunted.

Simplifying the Balancing Condition:

Since $P = Q$, we have:

$$\frac{3}{3} = \frac{3}{S_{\text{eff}}}$$

This simplifies to:

$$S_{\text{eff}} = 3\,\Omega$$

Shunting S:

The effective resistance S_{eff} of S is given by the parallel combination of S and the shunt resistor R_{shunt}:

$$\frac{1}{S_{\text{eff}}} = \frac{1}{S} + \frac{1}{R_{\text{shunt}}}$$

Substitute $S = 4\,\Omega$ and $S_{\text{eff}} = 3\,\Omega$:

$$\frac{1}{3} = \frac{1}{4} + \frac{1}{R_{\text{shunt}}}$$

Solve for $\frac{1}{R_{\text{shunt}}}$:

$$\frac{1}{R_{\text{shunt}}} = \frac{1}{3} - \frac{1}{4}$$

Find the common denominator:

$$\frac{1}{R_{\text{shunt}}} = \frac{4}{12} - \frac{3}{12} = \frac{1}{12}$$

Thus:

$$R_{\text{shunt}} = 12\,\Omega$$

Quick Tip

The Wheatstone bridge is balanced when the ratio of resistances in opposite arms is equal. Use this condition to solve for unknown resistances.

---

26. Magnetic moment of a thin bar magnet is 'M'. If it is bent into a semi-circular form, its new magnetic moment will be _______________________.

Fill in the blank with the correct answer from the options given below.

(1) M/π

(2) $M/2$

(3) M

(4) $2M/\pi$

Answer: (4) $2M/\pi$

Solution:

Let the length of the bar magnet be $2l$. Its magnetic moment $M = m(2l)$, where m is the pole strength. When it is bent into a semicircle, the length of the semicircle is πl. The magnetic moment becomes: $M' = m(\pi l) = m(\pi/2)(2l) = M(\pi/2)$

The new magnetic moment is: $M' = m(\pi l) = m(\pi/2)(2l) = M(\pi/2) = 2M/\pi$

Quick Tip

The magnetic moment of a magnet depends on its pole strength and the distance between its poles. When the shape changes, the magnetic moment also changes.

---

27. Ferromagnetic material used in Transformers must have ______________________.
Fill in the blank with the correct answer from the options given below.
(1) Low permeability and High Hysteresis loss
(2) High permeability and Low Hysteresis loss
(3) High permeability and High Hysteresis loss
(4) Low permeability and Low Hysteresis loss

Answer: (2) High permeability and Low Hysteresis loss
Solution:
Transformers require materials with high permeability to maximize magnetic flux linkage and low hysteresis loss to minimize energy dissipation in the form of heat.

Quick Tip

Ferromagnetic materials used in transformers should exhibit high permeability for efficient flux transfer and low hysteresis loss to reduce energy waste.

---

28. A conducting ring of radius r is placed in a varying magnetic field perpendicular to the plane of the ring. If the rate at which the magnetic field varies is x, the electric field intensity at any point of the ring is ______________________.
Fill in the blank with the correct answer from the options given below.
(1) rx
(2) $rx/2$
(3) $2rx$
(4) $4\pi rx$

Answer: (2) $rx/2$
Solution:
According to Faraday's law of electromagnetic induction, the induced emf in a closed loop is equal to the negative of the rate of change of magnetic flux through the loop:
$\epsilon = -\frac{d\phi}{dt}$
For a circular ring of radius r in a magnetic field B perpendicular to the plane of the ring, the magnetic flux is given by $\phi = \pi r^2 B$. If B varies at a rate x, then:
$\frac{dB}{dt} = x$
$\epsilon = -\frac{d(\pi r^2 B)}{dt} = -\pi r^2 \frac{dB}{dt} = -\pi r^2 x$
The electric field intensity (E) is related to the induced emf by: $\epsilon = \oint \vec{E} \cdot d\vec{l}$ For a circular ring, $\epsilon = E(2\pi r)$ $E(2\pi r) = -\pi r^2 x$ $E = -rx/2$
The magnitude of the electric field is rx/2.

Quick Tip

Faraday's law relates the induced emf in a loop to the rate of change of magnetic flux through the loop. This induced emf generates an electric field.

---

29. A 50 Hz ac current of crest value 1 A flows through the primary of a transformer. If the mutual inductance between the primary and secondary be 0.5 H, the crest voltage induced in the secondary is ______________________.
Fill in the blank with the correct answer from the options given below.
(1) 75 V
(2) 150 V
(3) 100 V
(4) 200 V

Answer: (2) 150 V
Solution:
The induced emf in the secondary coil of a transformer is given by:
$e = -M\frac{dI}{dt}$
Where:

- e is the induced emf
- M is the mutual inductance
- $\frac{dI}{dt}$ is the rate of change of current

For a sinusoidal current, $I = I_0 \sin(\omega t)$, where I_0 is the crest value and $\omega = 2\pi f$ is the angular frequency. The rate of change of current is:
$\frac{dI}{dt} = I_0\omega \cos(\omega t)$
The crest value of $\frac{dI}{dt}$ is $I_0\omega = I_0(2\pi f)$. Therefore, the crest voltage induced in the secondary is:
$e_{crest} = MI_0(2\pi f) = 0.5 \times 1 \times (2\pi \times 50) = 50\pi \approx 150\,\text{V}$

Quick Tip

The induced emf in a transformer's secondary coil is proportional to the mutual inductance and the rate of change of current in the primary coil.

---

30. A long solenoid of diameter 0.1 m has 2×10^4 turns per meter. At the centre of the solenoid a coil of 100 turns and radius 0.01 m is placed with its axis coinciding with the solenoid axis. The current in the solenoid reduces at a constant rate to 0 A from 4 A in 0.05 s. If the resistance of the coil is $10\pi^2\,\Omega$, then the total charge flowing through the coil during this time is ______________________.
Fill in the blank with the correct answer from the options given below.
(1) $16\,\mu$C
(2) $32\,\mu$C
(3) $16\pi\,\mu$C
(4) $32\pi\,\mu$C

Answer: (2) $32\,\mu$**C**

Solution:
The magnetic field inside a solenoid is given by: $B = \mu_0 n I$ Where:

- B is the magnetic field
- μ_0 is the permeability of free space
- n is the number of turns per unit length
- I is the current

The magnetic flux through the coil is: $\phi = NBA = N(\mu_0 n I)(\pi r^2)$ where:

- N is the number of turns in the coil
- A is the area of the coil
- r is the radius of the coil

From Faraday's law:

$$|\epsilon| = N\frac{d\phi}{dt} = N\pi r^2 \mu_0 n \frac{dI}{dt}$$

$$\frac{dI}{dt} = \frac{4-0}{0.05} = 80\,\text{A/s}$$

$$|\epsilon| = 100 \times \pi(0.01)^2 \times (4\pi \times 10^{-7}) \times 2 \times 10^4 \times 80 = 32\pi \times 10^{-3}\,\text{V}$$

The total charge is given by: $Q = \frac{\epsilon}{R} = \frac{32\pi \times 10^{-3}}{10\pi^2} = \frac{32}{10\pi} \times 10^{-3} \approx 32\,\mu\text{C}$

Quick Tip

Faraday's law of induction relates the induced emf to the rate of change of magnetic flux. The total charge flowing through a circuit is the integral of current over time.

---

31. Lower half of a convex lens is made opaque. Which of the following statement describes the image of object placed in front of the lens?
(A) No change in image
(B) Image will show only half of the object
(C) Intensity of image gets reduced

Choose the correct answer from the options given below.
(1) (A) only
(2) (B) only
(3) (C) only
(4) (B) and (C) only

Answer: (C) only
Solution:
The problem involves a convex lens with its lower half made opaque, and we need to analyze how this affects the image formation.

Analysis of Statements:

- **(A) No change in image:** This is incorrect. Making the lower half of the lens opaque does not block light entirely but reduces the aperture of the lens. This results in a change in the intensity of the image, though the entire image is still formed.
- **(B) Image will show only half of the object:** This is incorrect. The image formation by a convex lens is not limited to the uncovered part of the lens. Even if part of the lens is covered, the remaining portion of the lens still forms the complete image of the object, as long as the object is in the lens's field of view.
- **(C) Intensity of image gets reduced:** This is correct. By making the lower half of the lens opaque, the effective aperture of the lens is reduced, allowing less light to pass through the lens. As a result, the intensity (brightness) of the image decreases.

Correct Statement:

The correct description is:

(C) Intensity of image gets reduced.

Quick Tip

The intensity of the image formed by a lens is directly proportional to the area of the lens used for image formation. If a portion of the lens is blocked, the intensity of the image will decrease.

---

32. Two slits are made 0.1 mm apart and the screen is placed 2 m away. The fringe separation when a light of wavelength 500 nm is used is ______________________.
Fill in the blank with the correct answer from the options given below.
(1) 1 cm
(2) 0.15 cm
(3) 1.5 cm
(4) 0.1 cm

Answer: (1) 1 cm
Solution:
The problem involves the calculation of fringe separation in a double-slit experiment. The formula for fringe separation is:

$$\Delta y = \frac{\lambda D}{d}$$

Where:

- λ is the wavelength of light ($\lambda = 500\,\text{nm} = 500 \times 10^{-9}\,\text{m}$),

- D is the distance between the slits and the screen ($D = 2\,\text{m}$),
- d is the distance between the two slits ($d = 0.1\,\text{mm} = 0.1 \times 10^{-3}\,\text{m}$).

Substitute the Values:

$$\Delta y = \frac{\lambda D}{d}$$

$$\Delta y = \frac{(500 \times 10^{-9})(2)}{0.1 \times 10^{-3}}$$

$$\Delta y = \frac{1000 \times 10^{-9}}{0.1 \times 10^{-3}}$$

$$\Delta y = \frac{1000}{0.1} \times 10^{-6} = 10 \times 10^{-2} = 0.1\,\text{m}$$

Convert to centimeters:

$$\Delta y = 0.1\,\text{m} = 1\,\text{cm}$$

> **Quick Tip**
>
> In Young's double-slit experiment, the fringe separation is directly proportional to the wavelength of light and the distance to the screen, and inversely proportional to the slit separation.

---

33. For an astronomical telescope having objective lens of focal length 10 m and eyepiece lens of focal length 10 cm, telescope's tube length and magnification respectively are ________________________.
Fill in the blank with the correct answer from the options given below.
(1) 20 cm, 1
(2) 1000 cm, 1
(3) 1010 cm, 1
(4) 1010 cm, 100

Answer: (4) 1010 cm, 100
Solution:
For an astronomical telescope, the tube length is approximately equal to the sum of the focal lengths of the objective and eyepiece lenses. The magnification is given by the ratio of the focal lengths of the objective and eyepiece lenses.
Tube length $= f_o + f_e = 1000\,\text{cm} + 10\,\text{cm} = 1010\,\text{cm}$
Magnification $= \frac{f_o}{f_e} = \frac{1000}{10} = 100$

> **Quick Tip**
>
> In an astronomical telescope, the objective lens has a long focal length, while the eyepiece has a short focal length. The magnification is the ratio of their focal lengths.

34. According to Bohr's Model
(A) The radius of the orbiting electron is directly proportional to n^2.
(B) The speed of the orbiting electron is directly proportional to $1/n$.
(C) The magnitude of the total energy of the orbiting electron is directly proportional to $1/n^2$.
(D) The radius of the orbiting electron is directly proportional to n^2.

Choose the correct answer from the options given below.
(1) (A), (B) and (C) only
(2) (A), (B), and (D) only
(3) (A), (B), (C) and (D)
(4) (B), (C) and (D) only

Answer: (4) (B), (C) and (D) only
Solution:

The question refers to the Bohr model of the hydrogen atom, which provides quantitative relationships for the behavior of an electron in orbit. Let us analyze each statement:
Analysis of Statements:
(A) The radius of the orbiting electron is directly proportional to n. According to Bohr's model, the radius of the orbit is given by:

$$r_n = n^2 \cdot r_1$$

where r_1 is the Bohr radius. Hence, the radius is proportional to n^2, not n. This statement is **incorrect**.
(B) The speed of the orbiting electron is directly proportional to $1/n$. The speed of the electron in the n-th orbit is given by:

$$v_n = \frac{v_1}{n}$$

where v_1 is the speed in the first orbit. Therefore, the speed is inversely proportional to n. This statement is **correct**.
(C) The magnitude of the total energy of the orbiting electron is directly proportional to $1/n^2$. The total energy in the n-th orbit is given by:

$$E_n = -\frac{E_1}{n^2}$$

where E_1 is the total energy of the electron in the first orbit. Thus, the magnitude of the energy is proportional to $1/n^2$. This statement is **correct**.
(D) The radius of the orbiting electron is directly proportional to n^2. As explained in (A), the radius is proportional to n^2. This statement is **correct**.
The correct statements are: (B), (C), and (D)

Quick Tip

A full-wave rectifier rectifies both halves of the AC input signal, resulting in an output frequency that is twice the input frequency.

35. For a full wave rectifier, if the input frequency is 50 Hz, the output frequency will be _____________________.

Fill in the blank with the correct answer from the options given below.
(1) 50 Hz
(2) 100 Hz
(3) 25 Hz
(4) 0 Hz

Answer: (2) 100 Hz

Solution:
A full-wave rectifier uses both the positive and negative halves of the input AC waveform to produce a pulsating DC output. The output frequency is twice the input frequency because two pulses of DC are produced for every complete cycle of the AC input.
Therefore, if the input frequency is 50 Hz, the output frequency will be $2 \times 50\,\text{Hz} = 100\,\text{Hz}$.

Quick Tip

A full-wave rectifier doubles the frequency of the input AC signal in the output pulsating DC signal.

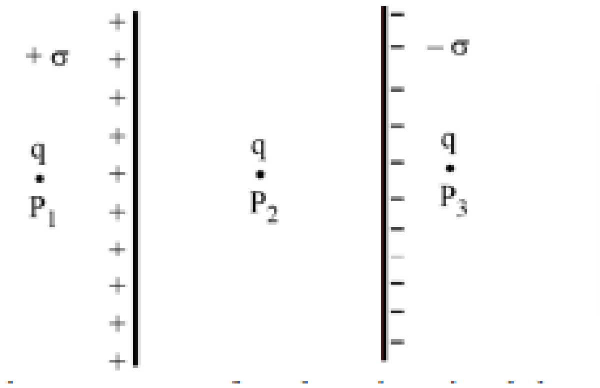
36. For an electric dipole in a non-uniform electric field with dipole moment parallel to direction of the field, the force F and torque T on the dipole respectively are _____________________.
Fill in the blank with the correct answer from the options given below.
(1) $F = 0, T = 0$
(2) $F \neq 0, T = 0$
(3) $F = 0, T \neq 0$
(4) $F \neq 0, T \neq 0$

Answer: (2) $F \neq 0, T = 0$
Solution:
In a uniform electric field, the net force on a dipole is zero, but there is a torque. In a non-uniform field, there is a net force and no torque if the dipole moment is parallel to the field.

Quick Tip

The force and torque experienced by an electric dipole in an electric field depend on the field's uniformity and the orientation of the dipole moment.

37. Two large plane parallel sheets shown in the figure have equal but opposite surface charge densities $+\sigma$ and $-\sigma$. A point charge q placed at points P_1, P_2 and P_3 experiences forces F_1, F_2 and F_3 respectively. Then ______________________.



Choose the correct answer from the options given below.
(1) $\vec{F_1} = 0$, $\vec{F_2} = 0$, $\vec{F_3} = 0$
(2) $\vec{F_1} = 0$, $\vec{F_2} \neq 0$, $\vec{F_3} = 0$
(3) $\vec{F_1} \neq 0$, $\vec{F_2} \neq 0$, $\vec{F_3} \neq 0$
(4) $\vec{F_1} = 0$, $\vec{F_2} \neq 0$, $\vec{F_3} = 0$

Answer: (2) $\vec{F_1} = 0$**,** $\vec{F_2} \neq 0$**,** $\vec{F_3} = 0$

Solution:
The electric field due to an infinite plane sheet of charge with uniform surface charge density σ is given by:
$E = \frac{\sigma}{2\epsilon_0}$
At point P_1, the fields due to the two sheets are equal and opposite, resulting in a net field of zero. Therefore, the force on charge q at P_1 is zero ($\vec{F_1} = 0$).
At point P_2, the fields due to the two sheets are in the same direction, resulting in a net field. Therefore, the force on charge q at P_2 is non-zero ($\vec{F_2} \neq 0$).
At point P_3, similar to P_1, the fields due to the two sheets are equal and opposite, resulting in a net field of zero. Therefore, the force on charge q at P_3 is zero ($\vec{F_3} = 0$).

Quick Tip

The electric field due to an infinite plane sheet of charge is uniform and perpendicular to the sheet. The field strength is independent of the distance from the sheet.

---

38. Two charged metallic spheres with radii R_1 and R_2 are brought in contact and then separated. The ratio of final charges Q_1 and Q_2 on the two spheres respectively will be ______________________.

Fill in the blank with the correct answer from the options given below.
(1) $\frac{Q_1}{Q_2} = \frac{R_2}{R_1}$

(2) $\frac{Q_1}{Q_2} < \frac{R_1}{R_2}$
(3) $\frac{Q_1}{Q_2} > \frac{R_1}{R_2}$
(4) $\frac{Q_1}{Q_2} = \frac{R_1}{R_2}$

Answer: (4) $\frac{Q_1}{Q_2} = \frac{R_1}{R_2}$

Solution:

When two conducting spheres are brought into contact, the charges redistribute until they reach the same potential. The potential on a sphere is given by $V = \frac{Q}{4\pi\epsilon_0 R}$, where Q is the charge and R is the radius. Since the potential is the same after contact, we have:

$$\frac{Q_1}{R_1} = \frac{Q_2}{R_2}$$

Thus, the ratio of charges is equal to the ratio of radii.

Quick Tip

When charged conductors are brought into contact, charge redistributes to equalize the electric potential on their surfaces.

---

39. Two charged particles, placed at a distance d apart in vacuum, exert a force F on each other. Now, each of the charges is doubled. To keep the force unchanged, the distance between the charges should be changed to ______________________.

Fill in the blank with the correct answer from the options given below.
(1) $4d$
(2) $2d$
(3) d
(4) $d/2$

Answer: (2) $2d$

Solution:

Coulomb's law states that the force between two point charges is given by:

$$F = k\frac{q_1 q_2}{r^2}$$

If each charge is doubled, and the force remains constant:

$$F = k\frac{(2q_1)(2q_2)}{r'^2} = k\frac{4q_1 q_2}{r'^2} = k\frac{q_1 q_2}{d^2}$$

Thus:

$$r'^2 = 4d^2$$

$$r' = 2d$$

Quick Tip

Coulomb's law describes the force between point charges. The force is inversely proportional to the square of the distance between the charges.

---

40. Two parallel plate capacitors of capacitances 2 μF and 3 μF are joined in series and the combination is connected to a battery of V volts. The values of potential across the two capacitors V_1 and V_2 and energy stored in the two capacitors U_1 and U_2 respectively are related as ______________________.

Fill in the blank with the correct answer from the options given below.
(1) $\frac{V_1}{V_2} = \frac{U_1}{U_2} = \frac{3}{2}$
(2) $\frac{V_1}{V_2} = \frac{U_1}{U_2} = \frac{2}{3}$
(3) $\frac{V_1}{V_2} = \frac{3}{2}$ and $\frac{U_1}{U_2} = \frac{2}{3}$
(4) $\frac{V_1}{V_2} = \frac{2}{3}$ and $\frac{U_1}{U_2} = \frac{3}{2}$

Answer: (1) $\frac{V_1}{V_2} = \frac{U_1}{U_2} = \frac{3}{2}$

Solution:
Two capacitors of capacitances $C_1 = 2\,\mu$F and $C_2 = 3\,\mu$F are connected in series. The relationship between the potential across the two capacitors (V_1 and V_2) and the energy stored in them (U_1 and U_2) can be determined as follows:
Step 1: Relationship Between Potentials (V_1 and V_2) For capacitors in series, the charge Q on each capacitor is the same, and the relationship between charge, capacitance, and potential is:

$$Q = C \cdot V$$

For the first capacitor:

$$Q = C_1 \cdot V_1$$

For the second capacitor:

$$Q = C_2 \cdot V_2$$

Since the charge is the same:

$$C_1 \cdot V_1 = C_2 \cdot V_2$$

Divide both sides by $C_1 \cdot C_2$:

$$\frac{V_1}{V_2} = \frac{C_2}{C_1}$$

Substitute $C_1 = 2\,\mu$F and $C_2 = 3\,\mu$F:

$$\frac{V_1}{V_2} = \frac{3}{2}$$

Step 2: Relationship Between Energies (U_1 and U_2) The energy stored in a capacitor is given by:

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

For the first capacitor:

$$U_1 = \frac{1}{2}C_1V_1^2$$

For the second capacitor:

$$U_2 = \frac{1}{2}C_2V_2^2$$

Take the ratio of the energies:

$$\frac{U_1}{U_2} = \frac{\frac{1}{2}C_1V_1^2}{\frac{1}{2}C_2V_2^2} = \frac{C_1}{C_2} \cdot \left(\frac{V_1}{V_2}\right)^2$$

Substitute $\frac{V_1}{V_2} = \frac{3}{2}$ and $C_1 = 2\,\mu\text{F}$, $C_2 = 3\,\mu\text{F}$:

$$\frac{U_1}{U_2} = \frac{2}{3} \cdot \left(\frac{3}{2}\right)^2$$

$$\frac{U_1}{U_2} = \frac{2}{3} \cdot \frac{9}{4} = \frac{18}{12} = \frac{3}{2}$$

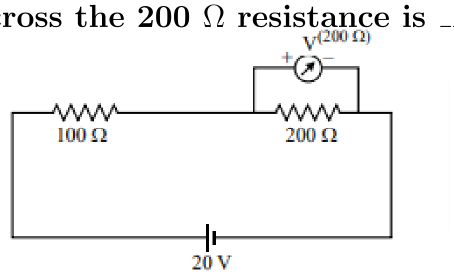
$$\frac{V_1}{V_2} = \frac{3}{2}, \quad \frac{U_1}{U_2} = \frac{3}{2}$$

Quick Tip

For capacitors in series, the charge is the same on each capacitor, but the voltage is inversely proportional to the capacitance.

---

41. Two resistances of 100 Ω and 200 Ω are connected in series across a 20 V battery as shown in figure below. The reading in a 200 Ω voltmeter connected across the 200 Ω resistance is ______________________.



Fill in the blank with the correct answer from the options given below.
(1) 4 V
(2) $\frac{20}{3}$ V
(3) 10 V
(4) 16 V

Answer: (3) 10 V

Solution:

The voltage across the 200 resistor is given by the voltage divider rule:
V200 = (200/(100+200)) × 20V = (2/3) × 20V = 40/3 V 13.33 V
This is not in the options. Let's consider the voltmeter's internal resistance.
The voltmeter is connected in parallel with the 200 resistor. The equivalent resistance is:
Req = (200 × 200)/(200+200) = 100
The total resistance is 100 + 100 = 200
The current is:
I = 20V/200 = 0.1 A
The voltage across 100 resistor is:
V100 = 0.1 A × 100 = 10V
The voltage across the voltmeter is 10 V.

Quick Tip

When a voltmeter is connected across a resistor, it forms a parallel combination. The reading on the voltmeter may be affected by the voltmeter's internal resistance. Use the voltage divider rule for series resistors.

---

42. The current through a 4/3 Ω external resistance connected to a parallel combination of two cells of 2 V and 1 V emf and internal resistances of 1 Ω and 2 Ω respectively is ______________________.
Fill in the blank with the correct answer from the options given below.
(1) 1 A
(2) 2/3 A
(3) 3/4 A
(4) 5/6 A

Answer: (4) 5/6 A
Solution:
The problem involves calculating the current through an external resistance connected to a parallel combination of two cells with given EMFs and internal resistances.
Given Data:

- EMFs of the two cells: $E_1 = 2\,\text{V}$, $E_2 = 1\,\text{V}$,
- Internal resistances: $r_1 = 1\,\Omega$, $r_2 = 2\,\Omega$,
- External resistance: $R = \frac{4}{3}\,\Omega$.

Step 1: Effective EMF of the Parallel Combination
For cells connected in parallel, the effective EMF (E_{eff}) is given by:

$$E_{\text{eff}} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}}$$

Substitute the values of E_1, E_2, r_1, and r_2:

$$E_{\text{eff}} = \frac{\frac{2}{1} + \frac{1}{2}}{\frac{1}{1} + \frac{1}{2}}$$

Simplify the numerator and denominator:

$$E_{\text{eff}} = \frac{2 + 0.5}{1 + 0.5} = \frac{2.5}{1.5}$$

$$E_{\text{eff}} = \frac{5}{3}\,\text{V}$$

Step 2: Effective Internal Resistance of the Parallel Combination The effective internal resistance (r_{eff}) for cells in parallel is given by:

$$\frac{1}{r_{\text{eff}}} = \frac{1}{r_1} + \frac{1}{r_2}$$

Substitute the values of r_1 and r_2:

$$\frac{1}{r_{\text{eff}}} = \frac{1}{1} + \frac{1}{2} = 1 + 0.5 = 1.5$$

$$r_{\text{eff}} = \frac{1}{1.5} = \frac{2}{3}\,\Omega$$

Step 3: Total Resistance in the Circuit
The total resistance in the circuit is the sum of the effective internal resistance and the external resistance:

$$R_{\text{total}} = r_{\text{eff}} + R$$

Substitute $r_{\text{eff}} = \frac{2}{3}$ and $R = \frac{4}{3}$:

$$R_{\text{total}} = \frac{2}{3} + \frac{4}{3} = \frac{6}{3} = 2\,\Omega$$

Step 4: Current Through the Circuit
The current in the circuit is given by Ohm's law:

$$I = \frac{E_{\text{eff}}}{R_{\text{total}}}$$

Substitute $E_{\text{eff}} = \frac{5}{3}$ and $R_{\text{total}} = 2$:

$$I = \frac{\frac{5}{3}}{2} = \frac{5}{6}\,\text{A}$$

Quick Tip

For parallel combinations of cells, the equivalent emf and internal resistance need to be calculated before applying Ohm's law.

43. A metallic wire of uniform area of cross section has a resistance R, resistivity ρ and power rating P at V volts. The wire is uniformly stretched to reduce the radius to half the original radius. The values of resistance, resistivity and power rating at V volts are now denoted by R', ρ' and P' respectively. The corresponding values are correctly related as ______________________.

Fill in the blank with the correct answer from the options given below.

(1) $\rho' = 2\rho$, $R' = 16R$, $P' = P/16$

(2) $\rho' = \rho/2$, $R' = R/2$, $P' = P/2$

(3) $\rho' = \rho$, $R' = 16R$, $P' = P/16$

(4) $\rho' = \rho$, $R' = (1/16)R$, $P' = 16P$

Answer: (3) $\rho' = \rho$, $R' = 16R$, $P' = P/16$

Solution:

Resistivity is an intrinsic property and does not change on stretching. $R = \frac{\rho l}{A}$ Let the initial radius be r and the final radius be r/2. The volume remains constant, therefore: $A_1 l_1 = A_2 l_2$ $\pi r^2 l = \pi (r/2)^2 l'$ $l' = 4l$ The new resistance is: $R' = \frac{\rho l'}{A'} = \frac{\rho(4l)}{\pi(r/2)^2} = \frac{16\rho l}{\pi r^2} = 16R$ The power rating is: $P = \frac{V^2}{R}$ $P' = \frac{V^2}{R'} = \frac{V^2}{16R} = \frac{P}{16}$

Quick Tip

Resistivity is an intrinsic property, while resistance depends on the geometry of the conductor. Stretching a wire changes its length and cross-sectional area, affecting its resistance.

---

44. Three magnetic materials are listed below

(A) paramagnetics

(B) diamagnetics

(C) ferromagnetics

Choose the correct order of the materials in increasing order of magnetic susceptibility.

(1) (A), (B), (C)

(2) (C), (A), (B)

(3) (B), (A), (C)

(4) (B), (C), (A)

Answer: (3) (B), (A), (C)

Solution:

Diamagnetic materials have negative susceptibility. Paramagnetic materials have small positive susceptibility. Ferromagnetic materials have high positive susceptibility. Therefore, the correct increasing order is diamagnetics, paramagnetics, ferromagnetics.

Quick Tip

Magnetic susceptibility is a measure of how easily a material can be magnetized in an external magnetic field. Diamagnetic materials have negative susceptibility, paramagnetic materials have small positive susceptibility, and ferromagnetic materials have large positive susceptibility.

---

45. Two infinitely long straight parallel conductors carrying currents I_1 and I_2 are held at a distance d apart in vacuum. The force F on a length L of one of the conductors due to the other is ____________________.

Fill in the blank with the correct answer from the options given below.
(1) proportional to L but independent of $I_1 \times I_2$
(2) proportional to $I_1 \times I_2$ but independent of length L
(3) proportional to $I_1 \times I_2 \times L$
(4) proportional to $\frac{L}{I_1 \times I_2}$

Answer: (3) proportional to $I_1 \times I_2 \times L$

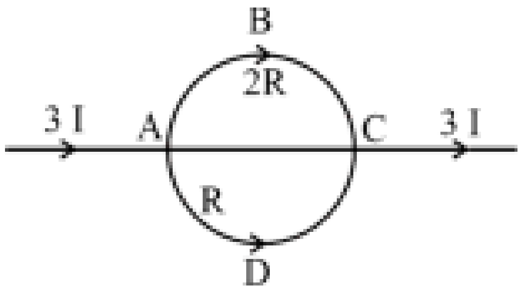
Solution:
The force per unit length between two infinitely long parallel conductors carrying currents I_1 and I_2 separated by a distance d is given by Ampere's law:
$F/L = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}$
Where μ_0 is the permeability of free space. The total force F on a length L is therefore:
$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}L$
This shows that the force F is directly proportional to the product of the currents $(I_1 \times I_2)$ and the length (L).

Quick Tip

The force between two parallel current-carrying conductors is directly proportional to the product of the currents and the length of the conductors, and inversely proportional to the distance between them.

---

46. In the circuit shown below, a current 3I enters at A. The semicircular parts ABC and ADC have equal radii 'r' but resistances 2R and R respectively. The magnetic field at the center of the circular loop ABCD is ____________________.



Fill in the blank with the correct answer from the options given below.
(1) $\frac{\mu_0 I}{4r}$ out of the plane
(2) $\frac{\mu_0 I}{4r}$ into the plane
(3) $\frac{\mu_0 3I}{4r}$ out of the plane
(4) $\frac{\mu_0 3I}{4r}$ into the plane

Answer: (1) $\frac{\mu_0 I}{4r}$ out of the plane

Solution:
The problem involves calculating the magnetic field at the center of a circular loop consisting of two semicircles, ABC and ADC, with different resistances.
Given Data:

- Current entering at A: $3I$,
- Semicircle ABC has resistance $2R$,
- Semicircle ADC has resistance R,
- Radius of the semicircles: r.

Step 1: Current Division in the Two Semicircles
The current divides in the ratio of the inverse of resistances. The resistance of ABC is $2R$, and the resistance of ADC is R. The current through ABC and ADC is:

$$I_{ABC} = \frac{R}{2R + R} \cdot 3I = \frac{R}{3R} \cdot 3I = I$$

$$I_{ADC} = \frac{2R}{2R + R} \cdot 3I = \frac{2R}{3R} \cdot 3I = 2I$$

Step 2: Magnetic Field Contribution by Each Semicircle
The magnetic field at the center due to a semicircle carrying current I is given by:

$$B = \frac{\mu_0 I}{4r}$$

Magnetic field due to ABC: The current through ABC is $I_{ABC} = I$, so the magnetic field contribution is:

$$B_{ABC} = \frac{\mu_0 I}{4r}$$

This magnetic field points **into the plane** due to the right-hand rule.

Magnetic field due to ADC: The current through ADC is $I_{ADC} = 2I$, so the magnetic field contribution is:

$$B_{ADC} = \frac{\mu_0(2I)}{4r} = \frac{2\mu_0 I}{4r} = \frac{\mu_0 I}{2r}$$

This magnetic field points **out of the plane** due to the right-hand rule.

Step 3: Net Magnetic Field at the Center

The net magnetic field at the center is the algebraic sum of the two contributions:

$$B_{\text{net}} = B_{ADC} - B_{ABC}$$

Substitute the values:

$$B_{\text{net}} = \frac{\mu_0 I}{2r} - \frac{\mu_0 I}{4r}$$

$$B_{\text{net}} = \frac{\mu_0 I}{4r} \quad \text{(out of the plane).}$$

Quick Tip

The magnetic field at the center of a current-carrying loop is proportional to the current and inversely proportional to the radius. Use the superposition principle for multiple loops.

---

47. A square loop with each side 1 cm, carrying a current of 10 A, is placed in a magnetic field of 0.2 T. The direction of magnetic field is parallel to the plane of the loop. The torque experienced by the loop is ______________________.
Fill in the blank with the correct answer from the options given below.
(1) zero
(2) 2×10^{-4} Nm
(3) 2×10^{-2} Nm
(4) 2 Nm

Answer: (1) zero

Solution:

The problem involves calculating the torque experienced by a square loop carrying a current in a magnetic field.

Given Data:

- Side of the square loop: $l = 1\,\text{cm} = 0.01\,\text{m}$,
- Current through the loop: $I = 10\,\text{A}$,
- Magnetic field strength: $B = 0.2\,\text{T}$,
- The magnetic field is parallel to the plane of the loop.

Torque on a Current Loop:
The torque (τ) experienced by a current loop in a magnetic field is given by:

$$\tau = \mathbf{m} \times \mathbf{B} = mB \sin\theta$$

Where:

- $\mathbf{m}$ is the magnetic moment of the loop,
- B is the magnetic field strength,
- θ is the angle between the magnetic moment vector and the magnetic field vector.

Step 1: Magnetic Moment of the Loop
The magnetic moment of the loop is:

$$m = NIA$$

Where:

- $N = 1$ (number of turns of the loop),
- $I = 10\,\text{A}$ (current),
- $A = l^2 = (0.01)^2 = 1 \times 10^{-4}\,\text{m}^2$ (area of the loop).

Substitute the values:

$$m = 1 \cdot 10 \cdot 1 \times 10^{-4} = 1 \times 10^{-3}\,\text{A} \cdot \text{m}^2$$

Step 2: Torque Calculation
The torque is:

$$\tau = mB \sin\theta$$

Since the magnetic field is parallel to the plane of the loop, the angle θ between the magnetic moment and the magnetic field is $90°$:

$$\sin\theta = \sin 90° = 1$$

Substitute the values:

$$\tau = (1 \times 10^{-3}) \cdot (0.2) \cdot 1$$

$$\tau = 2 \times 10^{-4}\,\text{Nm}$$

Quick Tip

The torque on a current loop in a magnetic field is maximum when the plane of the loop is perpendicular to the field and zero when it is parallel.

---

48. In an ac circuit, the current leads the voltage by $\pi/2$. The circuit is ______________________.

Fill in the blank with the correct answer from the options given below.
(1) purely resistive
(2) should have circuit elements with resistance equal to reactance
(3) purely inductive
(4) purely capacitive

Answer: (4) purely capacitive
Solution:
In a purely capacitive AC circuit, the current leads the voltage by $\pi/2$. This is because the capacitor charges and discharges as the voltage changes, causing the current to lead the voltage.

> **Quick Tip**
>
> In an AC circuit, the phase relationship between current and voltage depends on the type of circuit elements present (resistive, inductive, capacitive).

---

49. In a pair of adjacent coils, for a change of current in one of the coils from 0 A to 10 A in 0.25 s, the magnetic flux in the adjacent coil changes by 15 Wb. The mutual inductance of the coils is ______________________.
Fill in the blank with the correct answer from the options given below.
(1) 120 H
(2) 12 H
(3) 1.5 H
(4) 0.75 H

Answer: (3) 1.5 H
Solution:
Mutual inductance (M) is defined by:

$$|\epsilon| = M\frac{dI}{dt}$$

The change in magnetic flux is 15 Wb, and the change in current is 10 A over 0.25 s. The induced emf is:

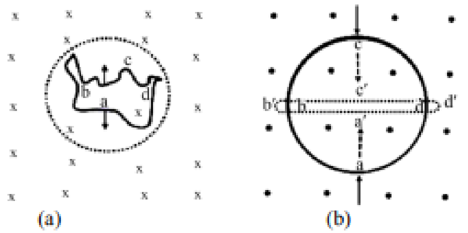
$$|\epsilon| = \frac{15}{0.25} = 60\,\text{V}$$

Using the mutual inductance equation:

$$M = \frac{|\epsilon|}{dI/dt} = \frac{60}{10/0.25} = \frac{60}{40} = 1.5\,\text{H}$$

> **Quick Tip**
>
> Mutual inductance quantifies the coupling between two coils. A change in current in one coil induces an emf in the other coil.

50. A wire of irregular shape in figure (a) and a circular loop of wire in figure (b), are placed in different uniform magnetic fields as shown in the figures below. In figure (a), the magnetic field is perpendicular into the plane. In figure (b), the magnetic field is perpendicular out of the plane.



The wire in figure (a) is turning into a circular loop and that in figure (b) into a narrow straight wire. The direction of induced current will be ____________________.

Fill in the blank with the correct answer from the options given below.
(1) clockwise in both (a) and (b)
(2) anticlockwise in both (a) and (b)
(3) clockwise in (a) and anticlockwise in (b)
(4) anticlockwise in (a) and clockwise in (b)

Answer: (2) anticlockwise in both (a) and (b)

Solution:
In case (a) area is increasing hence flux through the loop is increasing. The induced current will produced a magnetic field opposite to the existing magnetic field i.e out of the plane and hence direction of current is anti clock wise.
In case (b) area is decreasing hence flux through the loop is decreasing. The induced current will produced a magnetic field in the same direction as existing magnetic field i.e out of the plane and hence direction of current is anti clock wise.

Quick Tip

Lenz's law states that the direction of the induced current is such that it opposes the change in magnetic flux that produced it. Use the right-hand rule to determine the direction of the magnetic field produced by a current loop.