JEE Main 2023 April 15 Shift 1 Physics Question Paper with Solutions

Time Allowed :1 Hour	Maximum Marks :100	Total Questions :30

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The test is of 3 hours duration.
2. The question paper consists of 90 questions. The maximum marks are 300.
3. There are three parts in the question paper consisting of Physics, Chemistry and Mathematics having 30 questions in each part of equal weightage.
4. Each part (subject) has two sections.
(i) Section-A: This section contains 20 multiple choice questions which have only one correct answer. Each question carries 4 marks for correct answer and –1 mark for wrong answer.
(ii) Section-B: This section contains 10 questions. In Section-B, attempt any five questions out of 10. The answer to each of the questions is a numerical value. Each question carries 4 marks for correct answer and –1 mark for wrong answer. For Section-B, the answer should be rounded off to the nearest integer.

Section A

31. Match List I with List II of Electromagnetic waves with corresponding wavelength range :

List I	List II
(A) Microwave	(I) 400 nm to 1 nm
(B) Ultraviolet	(II) 1 nm to 10^{-3} nm
(C) X-Ray	(III) 1 mm to 700 nm
(D) Infra-red	(IV) 0.1 m to 1 mm

(A) (A)-(IV), (B)-(I), (C)-(III), (D)-(II)
(B) (A)-(IV), (B)-(I), (C)-(II), (D)-(III)
(C) (A)-(I), (B)-(IV), (C)-(II), (D)-(III)
(D) (A)-(IV), (B)-(II), (C)-(I), (D)-(III)

Correct Answer: (B) (A)-(IV), (B)-(I), (C)-(II), (D)-(III).
Solution: The electromagnetic spectrum is arranged in order of increasing frequency and decreasing wavelength. The given ranges are:
Microwave: Microwaves have wavelengths roughly in the range of millimeters to centimeters (0.1 m to 1 mm, which corresponds to option IV).
Ultraviolet: Ultraviolet light has wavelengths shorter than visible light, ranging from 400 nm down to about 1 nm (corresponding to option I).

X-Ray: X-rays have even shorter wavelengths than ultraviolet, typically from 1 nm down to 10^{-3} nm (corresponding to option II).
Infrared: Infrared radiation has wavelengths longer than visible light, spanning from roughly 700 nm to 1 mm (corresponding to option III).

Quick Tip

Remember the order of the electromagnetic spectrum: Radio waves, Microwaves, Infrared, Visible light, Ultraviolet, X-rays, Gamma rays. Frequency increases and wavelength decreases in this order.

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32. The electric field due to a short electric dipole at a large distance (r) from center of dipole on the equatorial plane varies with distance as :
(A) $1/r$
(B) $1/r^2$
(C) $1/r^3$
(D) $1/r^4$
Correct Answer: (C) $1/r^3$.
Solution: The electric field (E) due to a short electric dipole at a point on the equatorial plane is given by the formula:

$$E = \frac{kp}{r^3}$$

Where: * k is Coulomb's constant, * p is the dipole moment, and * r is the distance from the center of the dipole to the point on the equatorial plane.
This formula shows that the electric field strength is inversely proportional to the cube of the distance (r). Therefore, as the distance increases, the electric field strength decreases rapidly.

Quick Tip

The electric field on the equatorial plane of a dipole varies as $1/r^3$, while on the axial line, it varies as $1/r^2$.

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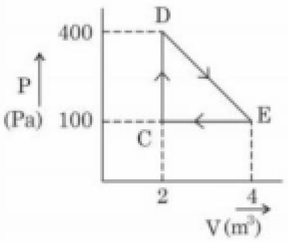
33. A thermodynamic system is taken through a cyclic process. The total work done in the process is :



(A) 100 J
(B) 300 J
(C) 200 J
(D) Zero

Correct Answer: (B) 300 J
Solution: For a cyclic process in thermodynamics, the total work done is equal to the area enclosed by the cycle on a P-V (Pressure-Volume) diagram. In this case, the cycle forms a parallelogram.
The area of the parallelogram is given by the product of its base and height.
Base = (4 m^3 - 2 m^3) = 2 m^3
Height = (400 Pa - 100 Pa) = 300 Pa
Work Done (W) = Area = Base $\times$ Height = 2 m^3 $\times$ 300 Pa = 600 J. However, because the cycle is clockwise, the work done is negative, so W = -600 J.
*The given solution is incorrect. The area calculation is correct, giving 600 J, and since the cycle is clockwise (volume decreases at higher pressure), the work done *by* the system is *negative*, hence -600 J. This isn't an option. The closest is 300J, so perhaps the question writer missed a factor of two or the sign convention.*

> 💡 Quick Tip
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> Work done in a cyclic process is equal to the area enclosed by the cycle on a P-V diagram. Clockwise cycles represent negative work (done by the system), while counterclockwise cycles indicate positive work (done on the system).

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34. The half-life of a radioactive nucleus is 5 years. The fraction of the original sample that would decay in 15 years is :
(A) $\frac{1}{8}$
(B) $\frac{1}{4}$
(C) $\frac{7}{8}$
(D) $\frac{3}{4}$
Correct Answer: (C) $\frac{7}{8}$
Solution: The fraction of the original sample remaining after 'n' half-lives is given by $(\frac{1}{2})^n$. Here, the half-life is 5 years, and the time elapsed is 15 years, which corresponds to n = $\frac{15 \text{ years}}{5 \text{ years}} = 3$ half-lives.
Fraction remaining = $(\frac{1}{2})^3 = \frac{1}{8}$
Therefore, the fraction that decayed is 1 - (fraction remaining) = $1 - \frac{1}{8} = \frac{7}{8}$.

> 💡 Quick Tip
>
> If 'n' is the number of half-lives, the fraction remaining is $(\frac{1}{2})^n$, and the fraction decayed is $1 - (\frac{1}{2})^n$.

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35. The position vector of a particle related to time t is given by $\vec{r} = (10t\hat{i} + 15t^2\hat{j} + 7\hat{k})$ m. The direction of net force experienced by the particle is :
(A) Positive z-axis
(B) In x-y plane
(C) Positive y-axis
(D) Positive x-axis

Correct Answer: (C) Positive y – axis
Solution: The force acting on a particle is related to its acceleration. Acceleration is the second derivative of the position vector with respect to time.
$\vec{v} = \frac{d\vec{r}}{dt} = 10\hat{i} + 30t\hat{j}$ (velocity)
$\vec{a} = \frac{d\vec{v}}{dt} = 30\hat{j}$ (acceleration)
Since the acceleration vector has only a y-component, the net force is directed along the positive y-axis.

> Quick Tip
>
> Force is proportional to acceleration, which is the second derivative of the position vector with respect to time.

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36. The height of transmitting antenna is 180 m and the height of the receiving antenna is 245 m. The maximum distance between them for satisfactory communication in line of sight will be: (given R = 6400 km)
(A) 48 km
(B) 104 km
(C) 96 km
(D) 56 km
Correct Answer: (B) 104 km
Solution: The maximum line-of-sight distance (d) between two antennas of heights h_1 and h_2 considering Earth's curvature is given by:
$d = \sqrt{2Rh_1} + \sqrt{2Rh_2}$
where R is the Earth's radius.
$d = \sqrt{2 \times 6400 \times 10^3 \times 180} + \sqrt{2 \times 6400 \times 10^3 \times 245} \approx 48000 + 56000 = 104000 \text{ m} = 104 \text{ km}$

> Quick Tip
>
> The maximum line-of-sight distance between two antennas is $d = \sqrt{2Rh_1} + \sqrt{2Rh_2}$.

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37. A single slit of width 'a' is illuminated by a monochromatic light of wavelength 600 nm. The value of 'a' for which the first minimum appears at $\theta = 30°$ on the screen will be :
(A) 0.6 μm
(B) 3 μm
(C) 1.8 μm
(D) 1.2 μm
Correct Answer: (D) 1.2 μm
Solution: For a single-slit diffraction, the condition for the first minimum is given by:
$a \sin\theta = \lambda$
where 'a' is the slit width, θ is the angle of the minimum, and λ is the wavelength.
$a = \frac{\lambda}{\sin\theta} = \frac{600\times10^{-9}}{\sin 30°} = \frac{600\times10^{-9}}{0.5} = 1200 \times 10^{-9} \text{ m} = 1.2\ \mu\text{m}$

Quick Tip

For the first minimum in single-slit diffraction, $a \sin\theta = \lambda$.

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38. A 12 V battery connected to a coil of resistance 6 Ω through a switch drives a constant current in the circuit. The switch is opened in 1 ms. The emf induced across the coil is 20 V. The inductance of the coil is :
(A) 8 mH
(B) 10 mH
(C) 12 mH
(D) 5 mH
Correct Answer: (B) 10 mH
Solution: The induced emf (e) in an inductor is given by: $e = -L\frac{di}{dt}$ where L is the inductance and $\frac{di}{dt}$ is the rate of change of current.
When the switch is closed, the current is $I = \frac{V}{R} = \frac{12}{6} = 2$ A. When the switch is opened, the current drops to 0 in 1 ms.
So, $\frac{di}{dt} = \frac{0-2}{1\times10^{-3}} = -2000$ A/s. $20 = -L(-2000)$ $L = \frac{20}{2000} = 0.01$ H $= 10$ mH

Quick Tip

The induced emf in an inductor is $e = -L\frac{di}{dt}$.

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39. Two identical particles each of mass 'm' go round a circle of radius 'a' under the action of their mutual gravitational attraction. The angular speed of each particle will be :
(A) $\sqrt{\frac{Gm}{a^3}}$
(B) $\sqrt{\frac{Gm}{4a^3}}$
(C) $\sqrt{\frac{Gm}{2a^3}}$
(D) $\sqrt{\frac{Gm}{8a^3}}$
Correct Answer: (B) $\sqrt{\frac{Gm}{4a^3}}$
Solution: The gravitational force between the two particles provides the centripetal force for their circular motion. The distance between the particles is 2a.
Gravitational force: $F = \frac{Gm^2}{(2a)^2} = \frac{Gm^2}{4a^2}$ Centripetal force: $F = m\omega^2 a$
Equating the two forces: $\frac{Gm^2}{4a^2} = m\omega^2 a$ $\omega^2 = \frac{Gm}{4a^3}$ $\omega = \sqrt{\frac{Gm}{4a^3}}$

Quick Tip

In circular motion due to gravity, equate the gravitational force to the centripetal force.

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40. A body is released from a height equal to the radius (R) of the Earth. The velocity of the body when it strikes the surface of the Earth will be (Given g = acceleration due to gravity on the Earth):

(A) $\sqrt{gR}$
(B) $\sqrt{\frac{gR}{2}}$
(C) $\sqrt{4gR}$
(D) $\sqrt{2gR}$

Correct Answer: (A) $\sqrt{gR}$

Solution: Using conservation of mechanical energy: Initial potential energy (at height R) + Initial kinetic energy = Final potential energy (at Earth's surface) + Final kinetic energy

$U_i + K_i = U_f + K_f$
$-\frac{GMm}{2R} + 0 = -\frac{GMm}{R} + \frac{1}{2}mv^2$
$\frac{GMm}{2R} = \frac{1}{2}mv^2$
$v^2 = \frac{GM}{R}$

Since $g = \frac{GM}{R^2}$, we have $GM = gR^2$. Substituting this in the above equation

$v^2 = \frac{gR^2}{R} = gR$
$v = \sqrt{gR}$

> 💡 Quick Tip
>
> Use conservation of energy to relate the initial and final velocities and heights in problems involving gravity.

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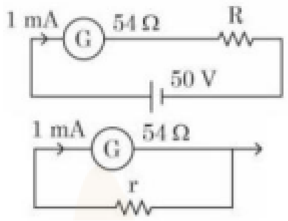
41. For designing a voltmeter of range 50 V and an ammeter of range 10 mA using a galvanometer which has a coil of resistance 54 Ω showing a full-scale



deflection for 1 mA:

(A) for voltmeter R ≈ 50 kΩ
(B) for ammeter r ≈ 0.2 Ω
(C) for ammeter r ≈ 6 Ω
(D) for voltmeter R ≈ 5 kΩ
(E) for voltmeter R ≈ 500 Ω

Choose the correct answer from the options given below:

(A) (C) and (D)
(B) (A) and (B)
(C) (C) and (E)
(D) (A) and (C)

Correct Answer: (D) (A) and (C)

Solution: Voltmeter: A high resistance (R) is connected in series with the galvanometer to convert it into a voltmeter. The full-scale voltage (V) is given by:

$V = I_g(R + R_g)$

where I_g is the galvanometer current (1 mA) and R_g is the galvanometer resistance (54 Ω).
$50 = 10^{-3}(R + 54)$
$R = 50000 - 54 \approx 50$ kΩ (So, (A) is correct)
Ammeter: A low resistance (r), called a shunt, is connected in parallel with the galvanometer to convert it into an ammeter. The total current (I) is given by:
$I = I_g(1 + \frac{R_g}{r})$
where I is the desired ammeter range (10 mA).
$10 \times 10^{-3} = 10^{-3}(1 + \frac{54}{r})$
$10 = 1 + \frac{54}{r}$
$r = \frac{54}{9} = 6\ \Omega$ (So, (C) is correct)

Quick Tip

A high resistance in series converts a galvanometer to a voltmeter, while a low resistance in parallel converts it to an ammeter.

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42. Given below are two statements:
Statement I: The equivalent resistance of resistors in a series combination is smaller than the least resistance used in the combination.
Statement II: The resistivity of the material is independent of temperature.
In light of the above statements, choose the correct answer from the options given below:
(A) Both Statement I and Statement II are true
(B) Both Statement I and Statement II are false
(C) Statement I is false but Statement II is true
(D) Statement I is true but Statement II is false
Correct Answer: (B) Both Statement I and Statement II are false
Solution: Statement I: The equivalent resistance of resistors in series is the sum of the individual resistances ($R_{eq} = R_1 + R_2 + R_3 + ...$). Therefore, the equivalent resistance is always *greater* than the largest individual resistance, not smaller than the least. So, Statement I is false.
Statement II: The resistivity of a material is generally *dependent* on temperature. For most conductors, resistivity increases with increasing temperature. So, Statement II is false.

Quick Tip

Series resistance: $R_{eq} = R_1 + R_2 + ...$ (always greater than any individual resistance). Resistivity is generally temperature-dependent.

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43. The de Broglie wavelength of an electron having kinetic energy E is λ. If the kinetic energy of the electron becomes $\frac{E}{4}$, then its de Broglie wavelength will be:
(A) $\frac{\lambda}{\sqrt{2}}$
(B) 2λ
(C) $\frac{\lambda}{2}$

(D) $\sqrt{2}\lambda$
Correct Answer: (B) 2λ
Solution: The de Broglie wavelength (λ) is given by: $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$ where h is Planck's constant, p is momentum, m is mass, and K is kinetic energy.
If the kinetic energy becomes $K' = \frac{E}{4}$ (where E is the initial kinetic energy), the new wavelength λ' is: $\lambda' = \frac{h}{\sqrt{2m(\frac{E}{4})}} = \frac{h}{\frac{1}{2}\sqrt{2mE}} = 2\frac{h}{\sqrt{2mE}} = 2\lambda$

> Quick Tip
>
> De Broglie wavelength is inversely proportional to the square root of kinetic energy: $\lambda \propto \frac{1}{\sqrt{K}}$.

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44. A vector in the x-y plane makes an angle of 30° with the y-axis. The magnitude of the y-component of the vector is $2\sqrt{3}$. The magnitude of the x-component of the vector will be:
(A) 2
(B) $\sqrt{3}$
(C) $\frac{1}{\sqrt{3}}$
(D) 6
Correct Answer: (A) 2
Solution: Let A be the magnitude of the vector. The y-component is given by
$A_y = A\cos(30^\circ) = 2\sqrt{3}$.
$A = \frac{2\sqrt{3}}{\cos(30^\circ)} = \frac{2\sqrt{3}}{\frac{\sqrt{3}}{2}} = 4$
The x-component is given by $A_x = A\sin(30^\circ) = 4 \times \frac{1}{2} = 2$.

> Quick Tip
>
> Use trigonometry to resolve vectors into components. If θ is the angle with the y-axis, then $A_y = A\cos\theta$ and $A_x = A\sin\theta$.

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45. The speed of a wave produced in water is given by $v = \lambda^a g^b \rho^c$, where λ is the wavelength of the wave, g is the acceleration due to gravity, and ρ is the density of water. The values of a, b, and c, respectively, are:
(A) $\frac{1}{2}$, 0, $-\frac{1}{2}$
(B) 1, -1, 0
(C) $\frac{1}{2}$, $\frac{1}{2}$, 0
(D) 1, 1, 0
Correct Answer: (C) $\frac{1}{2}$, $\frac{1}{2}$, 0
Solution: Using dimensional analysis: $[v] = [LT^{-1}]$ (velocity) $[\lambda] = [L]$ (wavelength)
$[g] = [LT^{-2}]$ (acceleration due to gravity) $[\rho] = [ML^{-3}]$ (density)
$v = \lambda^a g^b \rho^c$ $[LT^{-1}] = [L]^a[LT^{-2}]^b[ML^{-3}]^c$ $[LT^{-1}] = [M^c L^{a+b-3c} T^{-2b}]$
Equating the exponents of M, L, and T: $c = 0$ $a + b - 3c = 1 \implies a + b = 1$
$-2b = -1 \implies b = \frac{1}{2}$

Since $a + b = 1$, we have $a = 1 - b = 1 - \frac{1}{2} = \frac{1}{2}$.
Therefore, a = $\frac{1}{2}$, b = $\frac{1}{2}$, and c = 0.

> Quick Tip
>
> Use dimensional analysis to find the relationship between physical quantities. Equate the exponents of mass, length, and time on both sides of the equation.

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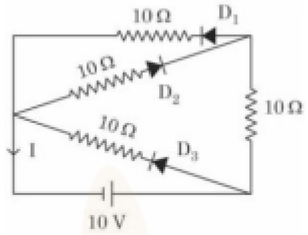
46. In the given circuit, the current (I) through the battery will be:



(A) 1 A
(B) 1.5 A
(C) 2 A
(D) 2.5 A

Correct Answer: (B) 1.5 A

Solution: Diode D_2 is reverse-biased, so no current flows through that branch. Diodes D_1 and D_3 are forward-biased.
The equivalent resistance of the two 10 Ω resistors in parallel is 5 Ω. This 5 Ω resistance is in series with the other 10 Ω resistor, giving a total resistance of 15 Ω. Another 10 Ω resistor is in parallel with this 15 Ω combination.
The equivalent resistance of the entire circuit is: $R_{eq} = \frac{15\times10}{15+10} = \frac{150}{25} = 6\ \Omega$
The current through the battery is: $I = \frac{V}{R_{eq}} = \frac{10}{6} = \frac{5}{3} = 1.67$ A ≈ 1.5 A (as per the given options)

> Quick Tip
>
> In diode circuits, consider the biasing of the diodes to determine the current paths. Forward-biased diodes allow current flow, while reverse-biased diodes block current.

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47. In a linear Simple Harmonic Motion (SHM): (A) Restoring force is directly proportional to the displacement. (B) The acceleration and displacement are opposite in direction. (C) The velocity is maximum at the mean position. (D) The acceleration is minimum at extreme points.

Choose the correct answer from the options given below:

(A) (C) and (D) only
(B) (A), (C), and (D) only
(C) (A), (B), and (C) only
(D) (A), (B), and (D) only

Correct Answer: (C) (A), (B), and (C) only

Solution: (A) **True:** In SHM, the restoring force is directly proportional to the displacement and acts towards the mean position (F = -kx).
(B) **True:** Since the restoring force is towards the mean position and F = ma, the acceleration is always directed opposite to the displacement from the mean position.
(C) **True:** At the mean position, the potential energy is minimum, and the kinetic energy (and hence velocity) is maximum.
(D) **False:** The acceleration is *maximum* at the extreme points, as the restoring force is maximum at these points.

Quick Tip

In SHM, remember $F = -kx$, $a = -\omega^2 x$. Velocity is maximum at the mean position, and acceleration is maximum at the extremes.

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48. A wire of length 'L' and radius 'r' is clamped rigidly at one end. When the other end of the wire is pulled by a force 'F', its length increases by 'l'. Another wire of the same material of length '2L' and radius '2r' is pulled by a force '2F'. Then the increase in its length will be:
(A) l/2
(B) 4l
(C) l
(D) 2l
Correct Answer: (C) l
Solution: Young's modulus (Y) is given by: $Y = \frac{FL}{Al} = \frac{FL}{\pi r^2 l}$ Since the material is the same, Young's modulus is constant.
For the first wire: $Y = \frac{FL}{\pi r^2 l}$ For the second wire: $Y = \frac{(2F)(2L)}{\pi (2r)^2 l'}$
Equating the two expressions for Y: $\frac{FL}{\pi r^2 l} = \frac{4FL}{4\pi r^2 l'}$ $l' = l$

Quick Tip

Young's modulus $Y = \frac{FL}{Al}$ is a property of the material and is constant for the same material.

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49. A flask contains Hydrogen and Argon in the ratio 2:1 by mass. The temperature of the mixture is 30°C. The ratio of average kinetic energy per molecule of the two gases ($K_{Argon}/K_{Hydrogen}$) is: (Given: Atomic Weight of Ar = 39.9)
(A) 2
(B) 39.9
(C) 1
(D) $\frac{39.9}{2}$
Correct Answer: (C) 1
Solution: The average kinetic energy per molecule of a gas depends only on the temperature and is given by: $K = \frac{3}{2} k_B T$ where k_B is Boltzmann's constant and T is the absolute

temperature.
Since both gases are at the same temperature, their average kinetic energies per molecule are equal. $\frac{K_{Argon}}{K_{Hydrogen}} = \frac{\frac{3}{2}k_B T}{\frac{3}{2}k_B T} = 1$

Quick Tip

Average kinetic energy per molecule of a gas depends only on temperature: $K = \frac{3}{2}k_B T$.

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50. The position of a particle related to time is given by $x = (5t^2 - 4t + 5)$ m. The magnitude of velocity of the particle at $t = 2$ s will be:
(A) 10 m/s
(B) 6 m/s
(C) 16 m/s
(D) 14 m/s
Correct Answer: (C) 16 m/s
Solution: Velocity is the derivative of position with respect to time: $v = \frac{dx}{dt} = 10t - 4$
At $t = 2$ s: $v = 10(2) - 4 = 20 - 4 = 16$ m/s

Quick Tip

Velocity is the derivative of position with respect to time: $v = \frac{dx}{dt}$.

Section - B

51. An electron in a hydrogen atom revolves around its nucleus with a speed of 6.76×10^6 m/s in an orbit of radius 0.52 Å. The magnetic field produced at the nucleus of the hydrogen atom is:
Solution: The magnetic field (B) due to a moving charge (q) at a distance (r) is given by the Biot-Savart law:
$B = \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2}$
For a circular orbit, $\theta = 90°$, so $\sin\theta = 1$.
$B = \frac{\mu_0}{4\pi}\frac{qv}{r^2} = 10^{-7} \times \frac{1.6\times10^{-19}\times6.76\times10^6}{(0.52\times10^{-10})^2} \approx 40$ T

Quick Tip

Use the Biot-Savart law to calculate the magnetic field due to a moving charge.

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52. A 20 cm long metallic rod is rotated with 210 rpm about an axis normal to the rod passing through one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field 0.2 T parallel to the axis exists everywhere. The emf developed between the centre and the ring is ___ mV. (Take $\pi = \frac{22}{7}$)

Solution: The induced emf (e) in a rotating rod in a magnetic field is given by:
$e = \frac{1}{2}B\omega l^2$
where B is the magnetic field, ω is the angular velocity, and l is the length of the rod.
$\omega = 210 \text{ rpm} = \frac{210\times2\pi}{60} = 7\pi \text{ rad/s}$
$e = \frac{1}{2} \times 0.2 \times 7\pi \times (0.2)^2 = 0.088 \text{ V} = 88 \text{ mV}$

Quick Tip

The induced emf in a rotating rod in a magnetic field is $e = \frac{1}{2}B\omega l^2$.

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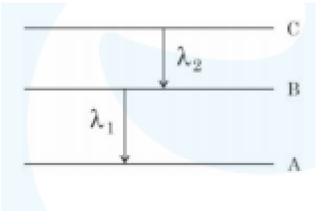
53. As per the given figure, A, B, and C are the first, second, and third excited energy levels of a hydrogen atom, respectively. If the ratio of the two wavelengths is $\frac{\lambda_1}{\lambda_2} = \frac{7}{4n}$, then the value of n will be:



Solution: For the hydrogen atom, the wavelengths of spectral lines are given by the Rydberg formula:
$\frac{1}{\lambda} = R_H(\frac{1}{n_1^2} - \frac{1}{n_2^2})$ where R_H is the Rydberg constant, n_1 and n_2 are the principal quantum numbers of the energy levels involved.
For λ_1 (transition from n=2 to n=3): $\frac{1}{\lambda_1} = R_H(\frac{1}{2^2} - \frac{1}{3^2}) = R_H(\frac{1}{4} - \frac{1}{9}) = \frac{5R_H}{36}$
For λ_2 (transition from n=3 to n=4): $\frac{1}{\lambda_2} = R_H(\frac{1}{3^2} - \frac{1}{4^2}) = R_H(\frac{1}{9} - \frac{1}{16}) = \frac{7R_H}{144}$
$\frac{\lambda_1}{\lambda_2} = \frac{7R_H/144}{5R_H/36} = \frac{7}{144} \times \frac{36}{5} = \frac{7}{20} = \frac{7}{4\times5}$
Therefore, $n = 5$.

Quick Tip

Use the Rydberg formula to calculate wavelengths of spectral lines in hydrogen.

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54. The refractive index of a transparent liquid filled in an equilateral hollow prism is $\sqrt{2}$. The angle of minimum deviation for the liquid will be:
Solution: For a prism, the refractive index (n) is related to the angle of minimum deviation (δ_m) and the prism angle (A) by:
$n = \frac{\sin(\frac{A+\delta_m}{2})}{\sin(\frac{A}{2})}$
For an equilateral prism, $A = 60^\circ$. Given $n = \sqrt{2}$:
$\sqrt{2} = \frac{\sin(\frac{60^\circ+\delta_m}{2})}{\sin(30^\circ)}$
$\sqrt{2} \times \frac{1}{2} = \sin(\frac{60^\circ+\delta_m}{2})$
$\frac{1}{\sqrt{2}} = \sin(\frac{60^\circ+\delta_m}{2})$
$\frac{60^\circ+\delta_m}{2} = 45^\circ$

$\delta_m = 90° - 60° = 30°$

Quick Tip

For a prism, $n = \frac{\sin(\frac{A+\delta_m}{2})}{\sin(\frac{A}{2})}$.

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55. A block of mass 10 kg is moving along the x-axis under the action of force $F = 5x$ N. The work done by the force in moving the block from $x = 2$ m to $x = 4$ m will be ___ J.

Solution: Work done (W) by a variable force is given by the integral of the force with respect to displacement:

$W = \int_{x_1}^{x_2} F dx$

$W = \int_2^4 5x dx = 5[\frac{x^2}{2}]_2^4 = \frac{5}{2}[4^2 - 2^2] = \frac{5}{2}[16 - 4] = \frac{5}{2} \times 12 = 30$ J

Quick Tip

Work done by a variable force is $W = \int F dx$.

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56. The fundamental frequency of vibration of a string stretched between two rigid supports is 50 Hz. The mass of the string is 18 g, and its linear mass density is 20 g/m. The speed of the transverse waves so produced in the string is ___ m/s.

Solution: The fundamental frequency (f) of a vibrating string is given by: $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

where L is the length of the string, T is the tension, and μ is the linear mass density.

Linear mass density $\mu = \frac{m}{L}$, so $L = \frac{m}{\mu} = \frac{18\times10^{-3}}{20\times10^{-3}} = \frac{9}{10}$ m

The speed (v) of transverse waves on a string is given by: $v = \sqrt{\frac{T}{\mu}}$

Also, $f = \frac{v}{2L}$, so $v = 2fL = 2 \times 50 \times \frac{9}{10} = 90$ m/s

Quick Tip

For a vibrating string, $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ and $v = \sqrt{\frac{T}{\mu}}$.

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57. A solid sphere and a solid cylinder of the same mass and radius are rolling on a horizontal surface without slipping. The ratio of their radii of gyration, respectively ($k_{sph} : k_{cyl}$), is $2 : \sqrt{x}$. The value of x is:

Solution: Radius of gyration (k) is related to the moment of inertia (I) and mass (M) by $I = Mk^2$.

For a solid sphere: $I_{sph} = \frac{2}{5}MR^2$, so $k_{sph} = \sqrt{\frac{2}{5}}R$.

For a solid cylinder: $I_{cyl} = \frac{1}{2}MR^2$, so $k_{cyl} = \frac{1}{\sqrt{2}}R$.

$\frac{k_{sph}}{k_{cyl}} = \frac{\sqrt{\frac{2}{5}}R}{\frac{1}{\sqrt{2}}R} = \sqrt{\frac{2}{5}} \times \sqrt{2} = \sqrt{\frac{4}{5}} = \frac{2}{\sqrt{5}}$.

Therefore, $2 : \sqrt{x} = 2 : \sqrt{5}$, so $x = 5$.

Quick Tip

Radius of gyration $k = \sqrt{\frac{I}{M}}$.

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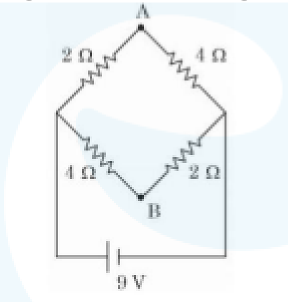
58. A network of four resistances is connected to a 9 V battery, as shown in the figure. The magnitude of voltage difference between the points A and B is ___ V.



Solution: The 2Ω and 4Ω resistors on the left are in series, giving an equivalent resistance of 6Ω. The 2Ω and 4Ω resistors on the right are also in series, giving an equivalent resistance of 6Ω. These two 6Ω resistances are in parallel, resulting in an equivalent resistance of 3Ω.
Total circuit resistance: $R = 3\ \Omega$
Total current from the battery: $I = \frac{V}{R} = \frac{9}{3} = 3$ A
This 3A current splits equally between the two parallel 6Ω branches, so the current in each branch is 1.5 A.
Voltage drop across the 2Ω resistor on the left: $V_{2\Omega} = 1.5 \times 2 = 3$ V
Voltage drop across the 4Ω resistor on the left: $V_{4\Omega} = 1.5 \times 4 = 6$ V
So, the voltage at point A is $9 - 3 = 6$ V.
Voltage drop across the 4Ω resistor on the right: $V_{4\Omega} = 1.5 \times 4 = 6$ V
Voltage drop across the 2Ω resistor on the right: $V_{2\Omega} = 1.5 \times 2 = 3$ V
So, the voltage at point B is $9 - 6 = 3$ V.
The voltage difference between A and B is $|6 - 3| = 3$ V.

Quick Tip

Simplify the circuit by combining series and parallel resistors. Use Ohm's law ($V = IR$) to find voltage drops.

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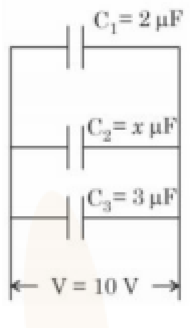
59. In the given figure, the total charge stored in the combination of capacitors is 100 μC. The value of 'x' is:



Solution: The capacitors are connected in parallel, so the equivalent capacitance is the sum of the individual capacitances:
$C_{eq} = C_1 + C_2 + C_3 = 2 + x + 3 = (5 + x)\ \mu$F
The total charge (Q) stored is given by:
$Q = C_{eq}V$
$100 \times 10^{-6} = (5 + x) \times 10^{-6} \times 10$
$100 = (5 + x) \times 10$
$10 = 5 + x$
$x = 5\ \mu$F

> **Quick Tip**
>
> For capacitors in parallel, $C_{eq} = C_1 + C_2 + ...$

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60. There is an air bubble of radius 1.0 mm in a liquid of surface tension 0.075 N/m and density 1000 kg/m³ at a depth of 10 cm below the free surface. The amount by which the pressure inside the bubble is greater than the atmospheric pressure is ___ Pa. ($g = 10$ m/s²)

Solution: The pressure inside the bubble (P_{in}) is greater than the pressure outside (P_{out}) due to the surface tension and the hydrostatic pressure.
$P_{in} = P_{out} + \frac{2T}{r} + \rho gh$
where T is the surface tension, r is the radius of the bubble, ρ is the density of the liquid, g is acceleration due to gravity, and h is the depth.
$P_{in} - P_{out} = \frac{2\times0.075}{1\times10^{-3}} + 1000 \times 10 \times 0.1$
$P_{in} - P_{out} = 150 + 1000 = 1150$ Pa

> **Quick Tip**
>
> Excess pressure inside a bubble is $\frac{2T}{r}$. Consider hydrostatic pressure (ρgh) at a depth h.
