Rajasthan JET Physics Sample Paper-10

Duration: 40 Minutes **Maximum Marks: 160**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1 marks**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. A particle moves along a straight line such that its displacement at any time t is given by $s = t^3 - 6t^2 + 9t + 4$, where s is in meters and t is in seconds. The velocity of the particle when its acceleration becomes zero is:

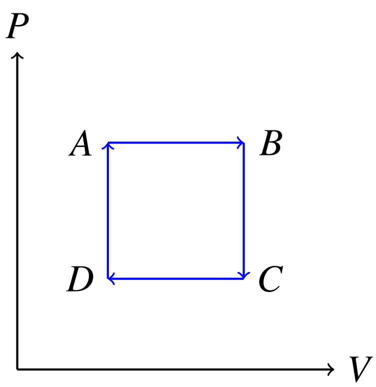
(A) -3 m/s

(B) 3 m/s

(C) -12 m/s

(D) 0 m/s

Q2. A thermodynamic system undergoes a cyclic process as shown in the P-V diagram. If the system absorbs 50 J of heat during the entire cycle, the net work done by the system in one complete cycle is:



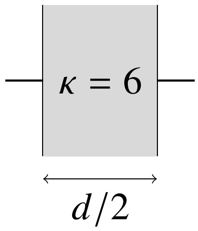
(A) -50 J

(B) 50 J

(C) 0 J

(D) 100 J

Q3. A parallel plate capacitor with air between the plates has a capacitance of 8 μF. What will be the capacitance if the distance between the plates is reduced by half and the space between them is filled with a substance of dielectric constant $\kappa = 6$?



(A) 24 μF

(B) 96 μF

(C) 48 μF

(D) 12 μF

Q4. Two bodies of masses 1 kg and 4 kg are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta is:

(A) 1 : 2

(B) 1 : 4

(C) 2 : 1

(D) 4 : 1

Q5. An astronomical telescope has an objective focal length of 140 cm and an eyepiece focal length of 5.0 cm. The magnifying power of the telescope for normal adjustment is:

(A) 145

(B) 28

(C) 70

(D) 35

Q6. The work function of a photosensitive material is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately:

(A) 310 nm

(B) 400 nm

(C) 496 nm

(D) 124 nm

Q7. If the error in the measurement of the radius of a sphere is 2%, then the error in the determination of its volume will be:

(A) 2%

(B) 4%

(C) 6%

(D) 8%

Q8. A liquid does not wet the solid surface if the angle of contact is:

(A) equal to 45°

(B) equal to 90°

(C) acute (less than 90°)

(D) obtuse (greater than 90°)

Q9. In a common-emitter amplifier, the audio signal voltage across the collector resistance of 2 kΩ is 2 V. If the base resistance is 1 kΩ and the current amplification factor is 100, the input signal voltage is:

(A) 0.1 V

(B) 0.01 V

(C) 1 V

(D) 10 mV

Q10. A body of mass m is taken from the Earth's surface to a height equal to the radius R of the Earth. The change in potential energy of the body will be:

(A) mgR

(B) $\frac{1}{2}mgR$

(C) $2mgR$

(D) $\frac{1}{4}mgR$

Q11. The fundamental frequency of a closed organ pipe is 250 Hz. If the pipe is opened at both ends, its fundamental frequency will become:

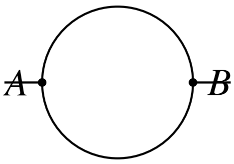
(A) 125 Hz

(B) 250 Hz

(C) 500 Hz

(D) 750 Hz

Q12. A wire of resistance 12 Ω is bent in the form of a uniform circle. The effective resistance between two points at the ends of any diameter of the circle is:



(A) 12 Ω

(B) 6 Ω

(C) 3 Ω

(D) 24 Ω

Q13. A bullet of mass 20 g moving with a speed of 100 m/s penetrates a sand bag and comes to rest in 0.05 s. The average retarding force acting on the bullet is:

(A) 40 N

(B) 20 N

(C) 80 N

(D) 100 N

Q14. The dynamic critical velocity of a liquid flowing through a cylindrical pipe depends on the density of the liquid ρ, its viscosity η, and the pipe radius r. The correct expression from dimensional analysis is proportional to:

(A) $\frac{\eta}{\rho r}$

(B) $\frac{\rho\eta}{r}$

(C) $\frac{\rho r}{\eta}$

(D) $\rho\eta r$

Q15. At what temperature will the root mean square (rms) speed of oxygen molecules be double of their rms speed at 27°C?

(A) 54°C

(B) 327°C

(C) 927°C

(D) 600°C

Q16. A long straight wire carries a current of 35 A. What is the magnitude of the magnetic field B at a point 20 cm away from the wire?

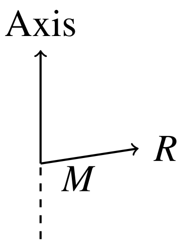
(A) 3.5×10^{-5} T

(B) 7.0×10^{-5} T

(C) 3.5×10^{-6} T

(D) 1.75×10^{-5} T

Q17. The moment of inertia of a uniform circular disc of mass M and radius R about an axis passing through its center and perpendicular to its plane is:



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

(B) $\frac{1}{2}MR^2$

(C) MR^2

(D) $2MR^2$

Q18. In Young's double-slit experiment, if the distance between the slits is halved and the distance between the slits and the screen is doubled, the fringe width will become:

(A) unchanged

(B) halved

(C) doubled

(D) four times

Q19. The half-life of a radioactive substance is 30 days. The time taken for $\frac{3}{4}$th of the original mass to disintegrate is:

(A) 60 days

(B) 15 days

(C) 90 days

(D) 45 days

Q20. A particle executing simple harmonic motion has a maximum velocity v_0 and a maximum acceleration a_0. The amplitude of its motion is given by:

(A) $\frac{v_0^2}{a_0}$

(B) $\frac{a_0^2}{v_0}$

(C) $\frac{v_0}{a_0}$

(D) $v_0 a_0$

Q21. An alternating current circuit contains a pure inductor of inductance 2.0 H. If the frequency of the AC source is 50 Hz, the inductive reactance of the circuit is approximately:

(A) 100 Ω

(B) 314 Ω

(C) 628 Ω

(D) 50 Ω

Q22. A vector $\vec{A}$ points vertically upwards and $\vec{B}$ points towards the North. The vector product $\vec{A} \times \vec{B}$ points towards:

(A) West

(B) East

(C) South

(D) Vertically downwards

Q23. Two absolute blocks of ice at 0°C are rubbed against each other, causing 4.2 g of ice to melt. The work done in this process is (L_f = 80 cal/g, 1 cal = 4.2 J):

(A) 336 J

(B) 1411.2 J

(C) 80 J

(D) 1680 J

Q24. According to Bohr's model of the hydrogen atom, the radius of the stationary electron orbit with principal quantum number n is directly proportional to:

(A) n

(B) n^2

(C) $\frac{1}{n}$

(D) $\frac{1}{n^2}$

Q25. A force $\vec{F} = (2\hat{i} + 3\hat{j} + 4\hat{k})$ N acts on a body and displaces it through $\vec{s} = (3\hat{i} + 4\hat{j} + 5\hat{k})$ m. The work done by the force is:

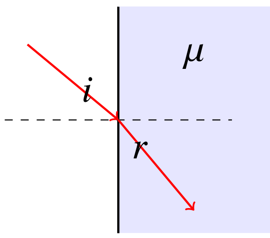
(A) 10 J

(B) 20 J

(C) 38 J

(D) 50 J

Q26. A ray of light passes from vacuum into a medium of refractive index μ. If the angle of incidence is twice the angle of refraction, then the angle of incidence is:



(A) $\cos^{-1}\left(\frac{\mu}{2}\right)$

(B) $2\cos^{-1}\left(\frac{\mu}{2}\right)$

(C) $\sin^{-1}\left(\frac{\mu}{2}\right)$

(D) $2\sin^{-1}\left(\frac{\mu}{2}\right)$

Q27. In an electromagnetic wave, the electric field vector $\vec{E}$ and magnetic field vector $\vec{B}$ are:

(A) parallel to each other and parallel to the direction of propagation.

(B) perpendicular to each other and parallel to the direction of propagation.

(C) parallel to each other and perpendicular to the direction of propagation.

(D) perpendicular to each other and perpendicular to the direction of propagation.

Q28. A projectile is thrown with an initial velocity of 50 m/s at an angle of 30° with the horizontal. The total time of flight of the projectile is ($g = 10$ m/s^2):

(A) 2.5 s

(B) 5.0 s

(C) 10 s

(D) 7.5 s

Q29. A black body radiates heat at a temperature of 127°C. To double the rate of radiation emission, its temperature must be raised to:

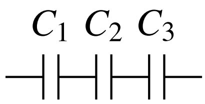
(A) 254°C

(B) 476 K

(C) 202°C

(D) 554 K

Q30. Three capacitors each of capacitance 9 pF are connected in series. The total capacitance of the combination is:



(A) 3 pF

(B) 9 pF

(C) 27 pF

(D) 1 pF

Q31. A circular coil of 100 turns and radius 10 cm carries a current of 0.40 A. The magnitude of the magnetic field at the center of the coil is:

(A) 2.5×10^{-4} T

(B) 5.0×10^{-4} T

(C) 2.5×10^{-5} T

(D) 1.25×10^{-4} T

Q32. A uniform heavy rope of mass M and length L hangs vertically from a rigid support. A transverse wave pulse is produced at the lower end. The speed of the wave pulse as it travels up the rope:

(A) remains constant throughout the length.

(B) decreases linearly as it moves upward.

(C) increases as it moves upward.

(D) first increases then decreases.

Q33. Two forces of magnitudes F and $2F$ act on a particle. If the first force is doubled and the second force is increased by 20 N, the direction of the resultant remains unaltered. The magnitude of F is:

(A) 10 N

(B) 20 N

(C) 5 N

(D) 15 N

Q34. In a sample of a pure semiconductor, if the temperature is increased, its electrical conductivity:

(A) decreases

(B) increases

(C) remains unaffected

(D) drops down to zero abruptly

Q35. A convex lens of focal length 20 cm in air is immersed entirely in water ($\mu_w = 4/3$). If the refractive index of glass is $\mu_g = 3/2$, its focal length in water becomes:

(A) 20 cm

(B) 40 cm

(C) 80 cm

(D) 10 cm

Q36. A potentiometer wire of length 10 m has a resistance of 20 Ω. It is connected in series with a battery of emf 3 V and negligible internal resistance. The potential gradient along the wire is:

(A) 0.3 V/m

(B) 0.15 V/m

(C) 0.6 V/m

(D) 1.5 V/m

Q37. The escape velocity of a body from the surface of the Earth depends on the mass of the body m as:

(A) m^0

(B) m^1

(C) m^2

(D) m^{-1}

Q38. The efficiency of a Carnot engine operating between temperatures 327°C and 27°C is:

(A) 50%

(B) 91.7%

(C) 11%

(D) 75%

Q39. An electron is accelerated through a potential difference of 100 V. The de Broglie wavelength associated with this electron is approximately:

(A) 1.227 nm

(B) 0.123 nm

(C) 12.27 nm

(D) 0.012 nm

Q40. A step-up transformer operates on a 220 V line and supplies a load of 2 A. The ratio of primary to secondary turns is 1 : 25. The current in the primary coil is (assuming 100% efficiency):

(A) 50 A

(B) 0.08 A

(C) 25 A

(D) 12.5 A

Detailed Solutions

Q1.

Solution

Concept: The relationship between position, velocity, and acceleration is found by differentiation. Velocity v is the first derivative of displacement s with respect to time t, and acceleration a is the derivative of velocity v with respect to time t.

Solution: Step 1: Write down the given expression for the displacement of the particle as a function of time:

$$s = t^3 - 6t^2 + 9t + 4$$

Step 2: Differentiate the displacement equation with respect to time t to find the velocity equation:

$$v = \frac{ds}{dt} = \frac{d}{dt}(t^3 - 6t^2 + 9t + 4) = 3t^2 - 12t + 9$$

Step 3: Differentiate the velocity equation with respect to time t to find the acceleration equation:

$$a = \frac{dv}{dt} = \frac{d}{dt}(3t^2 - 12t + 9) = 6t - 12$$

Step 4: Find the specific time t when the acceleration of the particle becomes zero by setting $a = 0$:

$$6t - 12 = 0 \implies 6t = 12 \implies t = 2 \text{ s}$$

Step 5: Substitute this time value $t = 2$ s back into the velocity equation to calculate the required velocity:

$$v = 3(2)^2 - 12(2) + 9 = 3(4) - 24 + 9 = 12 - 24 + 9 = -3 \text{ m/s}$$

Final Answer: -3 m/s

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: According to the first law of thermodynamics, for any closed system undergoing a cyclic process, the net change in internal energy (ΔU) over a complete cycle is zero. Therefore, the net heat absorbed by the system must equal the net work done by the system.

Solution: Step 1: State the first law of thermodynamics formula for a general thermodynamic process:

$$\Delta Q = \Delta U + \Delta W$$

Step 2: Identify the characteristic of a cyclic process. Since the system returns to its initial state, internal energy is a state function and its change over a cycle is:

$$\Delta U = 0$$

Step 3: Substitute the condition for a cyclic process into the first law of thermodynamics equation:

$$\Delta Q_{\text{net}} = \Delta W_{\text{net}}$$

Step 4: Use the given value of total heat absorbed by the thermodynamic system during the entire cycle:

$$\Delta Q_{\text{net}} = 50 \text{ J}$$

Step 5: Conclude that the net work done by the system during this complete cyclic process is equal to the net heat absorbed:

$$\Delta W_{\text{net}} = 50 \text{ J}$$

Final Answer: 50 J

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: The capacitance of a parallel plate capacitor is determined by the plate area, the separation distance, and the permittivity of the material between them. The formula with a dielectric medium is $C = \frac{\kappa\varepsilon_0 A}{d}$.

Solution: Step 1: Write down the expression for the initial capacitance of the air-filled parallel plate capacitor:

$$C_0 = \frac{\varepsilon_0 A}{d} = 8\ \mu\text{F}$$

Step 2: Note the modified physical parameters given in the problem statement:

$$\text{New distance } d' = \frac{d}{2}, \quad \text{Dielectric constant } \kappa = 6$$

Step 3: Set up the formula for the new capacitance C' with these modified parameters:

$$C' = \frac{\kappa\varepsilon_0 A}{d'} = \frac{6 \cdot \varepsilon_0 A}{\left(\frac{d}{2}\right)}$$

Step 4: Simplify the algebraic expression to relate the new capacitance back to the initial capacitance:

$$C' = 6 \cdot 2 \cdot \left(\frac{\varepsilon_0 A}{d}\right) = 12 \cdot C_0$$

Step 5: Substitute the given value of the initial capacitance to find the final numerical capacitance:

$$C' = 12 \cdot 8\ \mu\text{F} = 96\ \mu\text{F}$$

Final Answer: $96\ \mu\text{F}$

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: The relationship between the linear momentum p and the kinetic energy K of a moving body of mass m is given by the formula $p = \sqrt{2mK}$. This equation allows us to compare momenta when kinetic energy is constant.

Solution: Step 1: State the formula linking linear momentum p, mass m, and kinetic energy K:

$$K = \frac{p^2}{2m} \implies p = \sqrt{2mK}$$

Step 2: Identify the condition given in the problem, which specifies that both bodies possess equal kinetic energies:

$$K_1 = K_2 = K$$

Step 3: Write down the individual linear momentum expressions for the first and second bodies:

$$p_1 = \sqrt{2m_1K} \quad \text{and} \quad p_2 = \sqrt{2m_2K}$$

Step 4: Take the ratio of the two linear momenta equations, canceling out the common terms:

$$\frac{p_1}{p_2} = \frac{\sqrt{2m_1K}}{\sqrt{2m_2K}} = \sqrt{\frac{m_1}{m_2}}$$

Step 5: Substitute the given values of masses $m_1 = 1$ kg and $m_2 = 4$ kg into the simplified ratio:

$$\frac{p_1}{p_2} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

Final Answer: 1 : 2

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: For an astronomical telescope in normal adjustment, the final image is formed at infinity. The magnifying power m in this configuration is defined as the ratio of the focal length of the objective lens to the focal length of the eyepiece lens.

Solution: Step 1: Identify the given focal lengths for both components of the astronomical telescope system:

$$\text{Focal length of objective } f_o = 140 \text{ cm}$$

$$\text{Focal length of eyepiece } f_e = 5.0 \text{ cm}$$

Step 2: Recall the standard formula for the magnifying power m of a telescope in normal adjustment:

$$m = \frac{f_o}{f_e}$$

Step 3: Substitute the given numerical values of the focal lengths directly into the formula:

$$m = \frac{140}{5.0}$$

Step 4: Perform the mathematical division to find the absolute value of the magnifying power:

$$m = 28$$

Step 5: Note that magnification is a dimensionless ratio, representing how many times larger the angular size of the object appears.

Final Answer: 28

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: The threshold wavelength or longest wavelength (λ_0) required to cause photoelectric emission is related to the work function (ϕ) of the material by the equation $\phi = \frac{hc}{\lambda_0}$, where $hc \approx 1240$ eV · nm.

Solution: Step 1: Write down the fundamental equation for the work function in terms of the threshold wavelength:

$$\phi = \frac{hc}{\lambda_0}$$

Step 2: Rearrange the equation to express the maximum threshold wavelength as the subject:

$$\lambda_0 = \frac{hc}{\phi}$$

Step 3: Use the standard practical approximation value for the product of Planck's constant and speed of light:

$$hc \approx 1240 \text{ eV} \cdot \text{nm}$$

Step 4: Substitute the given work function value $\phi = 4.0$ eV into the rearranged expression:

$$\lambda_0 = \frac{1240 \text{ eV} \cdot \text{nm}}{4.0 \text{ eV}}$$

Step 5: Calculate the final value, noting that wavelengths longer than this cannot eject electrons:

$$\lambda_0 = 310 \text{ nm}$$

Final Answer: 310 nm

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: The fractional error in a quantity raised to a power is equal to the power multiplied by the fractional error in the base quantity. For a sphere, volume is proportional to the cube of its radius, $V \propto R^3$.

Solution: Step 1: Recall the standard geometric formula for calculating the total volume of a sphere:

$$V = \frac{4}{3}\pi R^3$$

Step 2: Write the relative error expression by taking the natural logarithm and differentiating both sides:

$$\frac{\Delta V}{V} = 3 \cdot \frac{\Delta R}{R}$$

Step 3: Convert the fractional error relationship into a percentage error expression by multiplying by 100:

$$\left(\frac{\Delta V}{V} \times 100\right) = 3 \cdot \left(\frac{\Delta R}{R} \times 100\right)$$

Step 4: Identify the given percentage error value in the measurement of the radius from the problem:

$$\frac{\Delta R}{R} \times 100 = 2\%$$

Step 5: Substitute this radius error into the percentage error equation to find the final volume error:

$$\text{Percentage error in Volume} = 3 \cdot 2\% = 6\%$$

Final Answer: 6%

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept: The angle of contact determines whether a liquid wets a solid surface. When cohesive forces between liquid molecules are stronger than adhesive forces between liquid and solid, the contact angle is obtuse, and wetting does not occur.

Solution: Step 1: Define the angle of contact (θ) as the angle between the tangent to the liquid surface and the solid surface inside the liquid.
Step 2: Analyze the conditions for wetting. If adhesive forces dominate over cohesive forces, $\theta < 90^\circ$ (acute), creating a concave meniscus where the liquid wets the surface.
Step 3: Analyze the conditions for non-wetting. If cohesive forces dominate over adhesive forces, the liquid tends to minimize contact, forming spherical droplets.
Step 4: Relate this non-wetting behavior to the geometry of the interface. This occurs when the angle of contact $\theta > 90^\circ$ (obtuse), forming a convex meniscus.
Step 5: Conclude that for a liquid that completely fails to wet a solid surface, the angle must be obtuse.

Final Answer: obtuse (greater than 90°)

Answer: (D)

Go Back to Question 8

Q9.

Solution

Concept: In a common-emitter amplifier circuit, the voltage gain (A_v) is defined as the ratio of output signal voltage (V_0) to input signal voltage (V_i). It can also be expressed as $A_v = \beta \cdot \frac{R_c}{R_b}$.

Solution: Step 1: Write down the primary formula for the voltage gain A_v of a common-emitter transistor amplifier:

$$A_v = \beta \cdot \frac{R_c}{R_b}$$

Step 2: Substitute the given parameters into the voltage gain equation:

$$\beta = 100, \quad R_c = 2\ \text{k}\Omega = 2000\ \Omega, \quad R_b = 1\ \text{k}\Omega = 1000\ \Omega$$

$$A_v = 100 \cdot \frac{2000}{1000} = 100 \cdot 2 = 200$$

Step 3: Recall the definition of voltage gain as the ratio of output voltage to input voltage:

$$A_v = \frac{V_0}{V_i}$$

Step 4: Rearrange this relationship to isolate the unknown input signal voltage V_i:

$$V_i = \frac{V_0}{A_v}$$

Step 5: Substitute the output signal voltage $V_0 = 2$ V and calculated gain to find the final result:

$$V_i = \frac{2\ \text{V}}{200} = 0.01\ \text{V}$$

Final Answer: 0.01 V

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: The gravitational potential energy of an object of mass m at a distance r from the center of the Earth is given by $U = -\frac{GMm}{r}$. The change in potential energy is calculated as $\Delta U = U_f - U_i$.

Solution: Step 1: Write down the expression for the initial gravitational potential energy at the surface of the Earth ($r_i = R$):

$$U_i = -\frac{GMm}{R}$$

Step 2: Determine the final position distance from the center when raised to a height $h = R$:

$$r_f = R + h = R + R = 2R$$

Step 3: Write down the expression for the final gravitational potential energy at this altitude:

$$U_f = -\frac{GMm}{2R}$$

Step 4: Set up the equation for the net change in potential energy and substitute the expressions:

$$\Delta U = U_f - U_i = \left(-\frac{GMm}{2R}\right) - \left(-\frac{GMm}{R}\right) = \frac{GMm}{R}\left(1 - \frac{1}{2}\right) = \frac{GMm}{2R}$$

Step 5: Use the acceleration due to gravity relation at the surface, $g = \frac{GM}{R^2} \implies \frac{GM}{R} = gR$:

$$\Delta U = \frac{1}{2}\left(\frac{GMm}{R}\right) = \frac{1}{2}mgR$$

Final Answer: $\boxed{\frac{1}{2}mgR}$

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: The fundamental frequency of a closed organ pipe of length L is given by $f_c = \frac{v}{4L}$. For an open organ pipe of the same length, the fundamental frequency is given by $f_o = \frac{v}{2L}$.

Solution: Step 1: State the formula for the fundamental frequency of a closed organ pipe:

$$f_c = \frac{v}{4L}$$

Step 2: Use the given frequency value for the closed organ pipe to set up an equation for $\frac{v}{L}$:

$$\frac{v}{4L} = 250 \text{ Hz} \implies \frac{v}{L} = 1000 \text{ Hz}$$

Step 3: State the formula for the fundamental frequency of an open organ pipe of identical length:

$$f_o = \frac{v}{2L}$$

Step 4: Express the open pipe frequency formula explicitly in terms of the closed pipe frequency:

$$f_o = 2 \cdot \left(\frac{v}{4L}\right) = 2 \cdot f_c$$

Step 5: Substitute the numerical value of $f_c = 250$ Hz to calculate the final open pipe frequency:

$$f_o = 2 \cdot 250 \text{ Hz} = 500 \text{ Hz}$$

Final Answer: 500 Hz

Answer: (C)

Go Back to Question 11

Q12.

Solution

Concept: When a uniform wire of resistance R is bent into a circle, any diameter divides it into two symmetrical semicircular segments. These two halves are connected in parallel between the diametrically opposite endpoints.

Solution: Step 1: Note the given total resistance of the straight uniform wire before bending:

$$R_{\text{total}} = 12\ \Omega$$

Step 2: Analyze the geometric effect of selecting two points at the ends of a diameter. The diameter splits the circumference into two equal halves.
Step 3: Since resistance is directly proportional to length ($R \propto l$), each semicircular half has exactly half of the total resistance:

$$R_1 = R_2 = \frac{R_{\text{total}}}{2} = \frac{12}{2} = 6\ \Omega$$

Step 4: Recognize that current entering one terminal splits between these two parallel branches before recombining at the other terminal.
Step 5: Apply the standard equivalent parallel resistance formula to find the net effective resistance:

$$R_{\text{eq}} = \frac{R_1 \cdot R_2}{R_1 + R_2} = \frac{6 \cdot 6}{6 + 6} = \frac{36}{12} = 3\ \Omega$$

Final Answer: $\boxed{3\ \Omega}$

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept: According to Newton's second law of motion, force is equal to the rate of change of linear momentum. The average retarding force can be calculated using the impulse-momentum equation $F = \frac{\Delta p}{\Delta t} = \frac{m(u-v)}{t}$.

Solution: Step 1: Convert all the given physical values into standard SI units for consistency:

$$\text{Mass of bullet } m = 20\text{ g} = 0.02\text{ kg}$$

$$\text{Initial velocity } u = 100\text{ m/s}, \quad \text{Final velocity } v = 0\text{ m/s (comes to rest)}$$

$$\text{Time interval } \Delta t = 0.05\text{ s}$$

Step 2: State the formula for the magnitude of the average retarding force acting on the bullet:

$$F = \frac{m(u - v)}{\Delta t}$$

Step 3: Substitute the numerical SI values into the average retarding force equation:

$$F = \frac{0.02 \cdot (100 - 0)}{0.05}$$

Step 4: Simplify the mathematical expression by performing the multiplication in the numerator:

$$F = \frac{2}{0.05}$$

Step 5: Complete the division to arrive at the final magnitude of the opposing force in Newtons:

$$F = 40\text{ N}$$

Final Answer: 40 N

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: Dimensional analysis is used to find relations between physical quantities by equating dimensions on both sides. The critical velocity v_c depends on density ρ, coefficient of viscosity η, and radius r.

Solution: Step 1: Write down the proportional relationship with unknown exponent powers a, b, and c:

$$v_c \propto \rho^a \eta^b r^c \implies v_c = k\rho^a \eta^b r^c$$

Step 2: Write down the basic dimensions for each of the physical variables involved:

$$[v_c] = [\mathrm{M^0L^1T^{-1}}], \quad [\rho] = [\mathrm{M^1L^{-3}T^0}]$$

$$[\eta] = [\mathrm{M^1L^{-1}T^{-1}}], \quad [r] = [\mathrm{M^0L^1T^0}]$$

Step 3: Substitute these dimensional formulas into the proportionality equation:

$$[\mathrm{M^0L^1T^{-1}}] = [\mathrm{M^1L^{-3}T^0}]^a [\mathrm{M^1L^{-1}T^{-1}}]^b [\mathrm{M^0L^1T^0}]^c$$

$$[\mathrm{M^0L^1T^{-1}}] = [\mathrm{M}^{a+b}\mathrm{L}^{-3a-b+c}\mathrm{T}^{-b}]$$

Step 4: Equate the corresponding exponents of M, L, and T from both sides:

$$\text{From T: } -b = -1 \implies b = 1$$

$$\text{From M: } a + b = 0 \implies a + 1 = 0 \implies a = -1$$

$$\text{From L: } -3a - b + c = 1 \implies -3(-1) - 1 + c = 1 \implies 3 - 1 + c = 1 \implies c = -1$$

Step 5: Substitute the values of $a = -1$, $b = 1$, and $c = -1$ back into the original relation:

$$v_c \propto \rho^{-1}\eta^1 r^{-1} \implies v_c \propto \frac{\eta}{\rho r}$$

Final Answer: $\boxed{\dfrac{\eta}{\rho r}}$

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: The root mean square (rms) speed of gas molecules is directly proportional to the square root of the absolute temperature measured in Kelvin, given by the kinetic theory formula $v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$.

Solution: Step 1: Write down the mathematical proportionality relation between rms speed and absolute temperature:

$$v_{\text{rms}} \propto \sqrt{T}$$

Step 2: Convert the initial temperature from degrees Celsius into the absolute Kelvin scale:

$$T_1 = 27^\circ\text{C} = 27 + 273 = 300 \text{ K}$$

Step 3: Set up the ratio equation for the initial and final states of the oxygen gas system:

$$\frac{v_{\text{rms}2}}{v_{\text{rms}1}} = \sqrt{\frac{T_2}{T_1}}$$

Step 4: Use the given condition that the final rms speed must be double the initial speed:

$$\frac{2 \cdot v_{\text{rms}1}}{v_{\text{rms}1}} = \sqrt{\frac{T_2}{300}} \implies 2 = \sqrt{\frac{T_2}{300}}$$

Step 5: Square both sides of the equation to eliminate the radical and solve for the final Kelvin and Celsius temperatures:

$$4 = \frac{T_2}{300} \implies T_2 = 1200 \text{ K}$$

$$t_2 = 1200 - 273 = 927^\circ\text{C}$$

Final Answer: $\boxed{927^\circ\text{C}}$

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept: According to Ampere's Law, the magnitude of the magnetic field B produced at a perpendicular distance r from an infinitely long straight wire carrying a steady current I is given by $B = \frac{\mu_0 I}{2\pi r}$.

Solution: Step 1: Write down the given physical quantities and convert them into standard metric SI units:

$$\text{Current } I = 35 \text{ A}$$

$$\text{Distance } r = 20 \text{ cm} = 0.2 \text{ m}$$

Step 2: State the formula for the magnetic field due to an infinitely long straight conductor:

$$B = \frac{\mu_0 I}{2\pi r}$$

Step 3: Substitute the constant value $\frac{\mu_0}{2\pi} = 2 \times 10^{-7}$ T · m/A into the main expression:

$$B = \left(\frac{\mu_0}{2\pi}\right) \cdot \frac{I}{r} = (2 \times 10^{-7}) \cdot \frac{35}{0.2}$$

Step 4: Perform the numerical simplification by dividing the values systematically:

$$B = (2 \times 10^{-7}) \cdot 175$$

Step 5: Express the final magnetic field value clearly in standard scientific notation format:

$$B = 350 \times 10^{-7} \text{ T} = 3.5 \times 10^{-5} \text{ T}$$

Final Answer: 3.5×10^{-5} T

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept: The moment of inertia measures a body's resistance to rotational acceleration. For a uniform circular disc of mass M and radius R, the integration of mass elements yields a standard value about its central perpendicular axis.

Solution: Step 1: Define the system as a flat, uniform circular disc with total mass M distributed uniformly over a surface area of πR^2.
Step 2: Set up the elemental mass element dm as a concentric ring of radius r and radial width dr:

$$dm = \frac{M}{\pi R^2} \cdot (2\pi r dr) = \frac{2M}{R^2} r dr$$

Step 3: Express the standard definition formula for the total moment of inertia by integration:

$$I = \int r^2 dm$$

Step 4: Substitute the expression for dm into the integration limits from 0 to R:

$$I = \int_0^R r^2 \left(\frac{2M}{R^2} r dr \right) = \frac{2M}{R^2} \int_0^R r^3 dr$$

Step 5: Evaluate the definite integral to arrive at the standard fundamental value:

$$I = \frac{2M}{R^2} \left[\frac{r^4}{4} \right]_0^R = \frac{2M}{R^2} \cdot \frac{R^4}{4} = \frac{1}{2} M R^2$$

Final Answer: $\boxed{\frac{1}{2} M R^2}$

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept: In Young's double-slit experiment, the fringe width (β) is the distance between two consecutive bright or dark fringes. The formula governing this pattern is $\beta = \frac{\lambda D}{d}$.

Solution: Step 1: Write down the standard formula for the initial fringe width in terms of system dimensions:

$$\beta = \frac{\lambda D}{d}$$

Step 2: Identify the precise modifications applied to the experimental setup from the problem description:

$$\text{New slit separation distance } d' = \frac{d}{2}$$

$$\text{New distance to screen } D' = 2D$$

Step 3: Set up the algebraic equation for the modified fringe width β' using the new values:

$$\beta' = \frac{\lambda D'}{d'} = \frac{\lambda(2D)}{\left(\frac{d}{2}\right)}$$

Step 4: Rearrange the fraction mathematically to separate the constant initial variables:

$$\beta' = 2 \cdot 2 \cdot \left(\frac{\lambda D}{d}\right) = 4\beta$$

Step 5: Conclude that the resulting fringe width expands to become exactly four times its initial value.

Final Answer: four times

Answer: (D)

Go Back to Question 18

Q19.

Solution

Concept: Radioactive decay follows first-order kinetics. The remaining amount of a radioactive substance after n half-lives is given by $N = N_0 \left(\frac{1}{2}\right)^n$, where total elapsed time is $t = n \cdot T_{1/2}$.

Solution: Step 1: Identify the fraction of the radioactive substance that has completely disintegrated:

$$\text{Disintegrated fraction} = \frac{3}{4}$$

Step 2: Calculate the remaining fraction N left intact at the end of the time period:

$$N = N_0 - \frac{3}{4}N_0 = \frac{1}{4}N_0 \implies \frac{N}{N_0} = \frac{1}{4}$$

Step 3: Equate this remaining fraction to the radioactive decay function in terms of half-life cycles n:

$$\left(\frac{1}{2}\right)^n = \frac{1}{4} = \left(\frac{1}{2}\right)^2 \implies n = 2$$

Step 4: State the total elapsed time formula as the product of number of half-lives and the half-life period:

$$t = n \cdot T_{1/2}$$

Step 5: Substitute the given value of half-life $T_{1/2} = 30$ days to find the total time:

$$t = 2 \cdot 30 \text{ days} = 60 \text{ days}$$

Final Answer: 60 days

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept: For a particle undergoing simple harmonic motion (SHM) with amplitude A and angular frequency ω, the maximum velocity is $v_0 = \omega A$ and the maximum acceleration magnitude is $a_0 = \omega^2 A$.

Solution: Step 1: Write down the expression for the maximum velocity attained by the particle in SHM:

$$v_0 = \omega A$$

Step 2: Write down the expression for the maximum acceleration magnitude of the particle in SHM:

$$a_0 = \omega^2 A$$

Step 3: Express the angular frequency ω from the first equation to substitute it into the second:

$$\omega = \frac{v_0}{A}$$

Step 4: Substitute this value of ω directly into the maximum acceleration equation:

$$a_0 = \left(\frac{v_0}{A}\right)^2 \cdot A = \frac{v_0^2}{A^2} \cdot A = \frac{v_0^2}{A}$$

Step 5: Rearrange the algebraic equation to isolate the amplitude parameter A explicitly:

$$A = \frac{v_0^2}{a_0}$$

Final Answer: $\boxed{\frac{v_0^2}{a_0}}$

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: Inductive reactance (X_L) is the opposition offered by an inductor to the flow of alternating current. It depends directly on the frequency of the AC source and is given by the formula $X_L = 2\pi f L$.

Solution: Step 1: Identify the given parameter values for the pure inductive AC circuit:

$$\text{Inductance } L = 2.0 \text{ H}, \quad \text{Source frequency } f = 50 \text{ Hz}$$

Step 2: State the standard formula used to compute the total inductive reactance:

$$X_L = \omega L = 2\pi f L$$

Step 3: Substitute the numerical values of frequency and inductance into the formula:

$$X_L = 2 \cdot \pi \cdot 50 \cdot 2.0$$

Step 4: Combine the numerical products systematically to simplify the expression:

$$X_L = 200\pi \ \Omega$$

Step 5: Substitute the numerical constant approximation for $\pi \approx 3.1416$ to get the final value:

$$X_L = 200 \cdot 3.1416 = 628.32 \ \Omega \approx 628 \ \Omega$$

Final Answer: $\boxed{628 \ \Omega}$

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept: The direction of a vector cross product $\vec{C} = \vec{A} \times \vec{B}$ is determined uniquely by the right-hand thumb rule, where the fingers curl from the first vector to the second vector.

Solution: Step 1: Set up a 3D orthogonal Cartesian coordinate system mapping geographical directions:

$$\text{Let East be along the } +x\text{-axis } (\hat{i})$$

$$\text{Let North be along the } +y\text{-axis } (\hat{j})$$

$$\text{Let Vertically Upwards be along the } +z\text{-axis } (\hat{k})$$

Step 2: Write down vector $\vec{A}$ and vector $\vec{B}$ in terms of these standard unit vectors:

$$\vec{A} = A\hat{k} \quad \text{(Vertically Upwards)}$$

$$\vec{B} = B\hat{j} \quad \text{(Towards North)}$$

Step 3: Set up the formal mathematical cross product expression for $\vec{A} \times \vec{B}$:

$$\vec{A} \times \vec{B} = (A\hat{k}) \times (B\hat{j}) = AB(\hat{k} \times \hat{j})$$

Step 4: Evaluate the fundamental cross product of the unit vectors using cyclic rules:

$$\hat{k} \times \hat{j} = -\hat{i}$$

Step 5: Interpret the physical direction of the resulting negative unit vector $-\hat{i}$:

$$\text{Since } +\hat{i} \text{ represents East, } -\hat{i} \text{ points directly West.}$$

Final Answer: West

Answer: (A)

Go Back to Question 22

Q23.

Solution

Concept: By conservation of energy, the mechanical work done against friction is entirely converted into heat energy. This heat energy is absorbed by the ice, causing a phase change governed by $Q = mL_f$.

Solution: Step 1: Identify the given quantities for the melting process:

$$\text{Mass of ice melted } m = 4.2 \text{ g}$$

$$\text{Latent heat of fusion } L_f = 80 \text{ cal/g}$$

Step 2: Calculate the net amount of heat energy required in calories to melt this mass of ice:

$$Q = m \cdot L_f = 4.2 \text{ g} \cdot 80 \text{ cal/g} = 336 \text{ calories}$$

Step 3: Recall the mechanical equivalent of heat conversion factor provided in the problem:

$$1 \text{ calorie} = 4.2 \text{ Joules}$$

Step 4: Set up the equation to convert the calculated heat energy from calories into Joules:

$$W = Q \times 4.2 = 336 \times 4.2$$

Step 5: Perform the multiplication to determine the total mechanical work performed:

$$W = 1411.2 \text{ Joules}$$

Final Answer: 1411.2 J

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept: In Bohr's atomic model for hydrogenic atoms, the orbital radius is quantized by balancing the electrostatic Coulomb force with the centripetal force, combined with angular momentum quantization ($mvr = \frac{nh}{2\pi}$).

Solution: Step 1: State the condition for angular momentum quantization in a stable Bohr orbit:

$$mvr = \frac{nh}{2\pi} \implies v = \frac{nh}{2\pi mr}$$

Step 2: Equate the centripetal force to the electrostatic force for a hydrogen atom ($Z = 1$):

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \implies mv^2 = \frac{e^2}{4\pi\varepsilon_0 r}$$

Step 3: Substitute the expression for velocity v from Step 1 into the force balance equation:

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{e^2}{4\pi\varepsilon_0 r} \implies \frac{mn^2h^2}{4\pi^2m^2r^2} = \frac{e^2}{4\pi\varepsilon_0 r}$$

Step 4: Isolate the radius variable r algebraically to determine its analytical expression:

$$r = \frac{n^2h^2\varepsilon_0}{\pi me^2}$$

Step 5: Group all constants together to establish the direct proportionality relationship:

$$r = \left(\frac{h^2\varepsilon_0}{\pi me^2}\right) \cdot n^2 \implies r \propto n^2$$

Final Answer: $\boxed{n^2}$

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: The work done W by a constant vector force $\vec{F}$ acting through a displacement vector $\vec{s}$ is calculated using the vector scalar dot product formula $W = \vec{F} \cdot \vec{s}$.

Solution: Step 1: Write down the components of the force vector and displacement vector given:

$$\vec{F} = 2\hat{i} + 3\hat{j} + 4\hat{k}$$

$$\vec{s} = 3\hat{i} + 4\hat{j} + 5\hat{k}$$

Step 2: State the operational mathematical definition of the dot product for work calculation:

$$W = \vec{F} \cdot \vec{s} = (F_x s_x) + (F_y s_y) + (F_z s_z)$$

Step 3: Substitute the respective directional components into the scalar product expression:

$$W = (2 \cdot 3) + (3 \cdot 4) + (4 \cdot 5)$$

Step 4: Compute the values of the individual terms resulting from component multiplication:

$$W = 6 + 12 + 20$$

Step 5: Sum the values to find the final scalar quantity of work in Joules:

$$W = 38 \text{ J}$$

Final Answer: 38 J

Answer: (C)

Go Back to Question 25

Q26.

Solution

Concept: According to Snell's Law of refraction, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is equal to the refractive index of the medium, $\mu = \frac{\sin i}{\sin r}$.

Solution: Step 1: Write down the expression for Snell's law governing refraction from vacuum:

$$\mu = \frac{\sin i}{\sin r}$$

Step 2: Use the specific angular relationship given in the problem statement:

$$i = 2r \implies r = \frac{i}{2}$$

Step 3: Substitute this relation back into the trigonometric expression of Snell's Law:

$$\mu = \frac{\sin i}{\sin(i/2)}$$

Step 4: Use the standard double-angle trigonometric identity for sine, $\sin i = 2\sin(i/2)\cos(i/2)$:

$$\mu = \frac{2\sin(i/2)\cos(i/2)}{\sin(i/2)} = 2\cos\left(\frac{i}{2}\right)$$

Step 5: Isolate the angle of incidence i by applying the inverse cosine function:

$$\cos\left(\frac{i}{2}\right) = \frac{\mu}{2} \implies \frac{i}{2} = \cos^{-1}\left(\frac{\mu}{2}\right) \implies i = 2\cos^{-1}\left(\frac{\mu}{2}\right)$$

Final Answer: $\boxed{2\cos^{-1}\left(\frac{\mu}{2}\right)}$

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept: Electromagnetic waves are transverse waves consisting of oscillating electric and magnetic fields. Maxwell's equations show that the electric field, magnetic field, and propagation direction are mutually perpendicular.

Solution: Step 1: State the characteristic property of electromagnetic waves: they are transverse in nature, meaning fields oscillate crosswise to the wave vector direction.
Step 2: Analyze the mathematical direction of wave propagation, which is defined by the Poynting vector cross product:

$$\hat{k} \propto \vec{E} \times \vec{B}$$

Step 3: From vector properties of cross products, the directional vector $\hat{k}$ must be simultaneously orthogonal to both constituent vectors $\vec{E}$ and $\vec{B}$.
Step 4: This implies that the electric field vector $\vec{E}$ is perpendicular to the propagation vector, and the magnetic field vector $\vec{B}$ is also perpendicular to the propagation vector.
Step 5: Combine these properties to conclude that $\vec{E}$ and $\vec{B}$ are perpendicular to each other, and both are perpendicular to the direction of propagation.

Final Answer: perpendicular to each other and perpendicular to the direction of propagation.

Answer: (D)

Go Back to Question 27

Q28.

Solution

Concept: The total time of flight T of a projectile launched from the ground with an initial velocity u at an angle θ relative to the horizontal is given by the kinematic expression $T = \frac{2u\sin\theta}{g}$.

Solution: Step 1: Identify all given kinematic parameters for the projectile launch:

$$\text{Initial velocity } u = 50 \text{ m/s}, \quad \text{Launch angle } \theta = 30^\circ, \quad g = 10 \text{ m/s}^2$$

Step 2: Recall the formula for the total time of flight derived from vertical motion components:

$$T = \frac{2u\sin\theta}{g}$$

Step 3: Substitute the numerical values directly into the flight time equation:

$$T = \frac{2 \cdot 50 \cdot \sin 30^\circ}{10}$$

Step 4: Use the standard trigonometric exact value for $\sin 30^\circ = \frac{1}{2}$:

$$T = \frac{100 \cdot \left(\frac{1}{2}\right)}{10} = \frac{50}{10}$$

Step 5: Perform the final division to find the total duration the projectile remains in the air:

$$T = 5 \text{ s} = 5.0 \text{ s}$$

Final Answer: 5.0 s

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept: According to the Stefan-Boltzmann Law, the total radiant energy emitted per unit surface area of a black body per unit time (E) is directly proportional to the fourth power of its absolute temperature, $E = \sigma T^4$.

Solution: Step 1: Write down the mathematical expression for the Stefan-Boltzmann Law:

$$E \propto T^4 \implies \frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4$$

Step 2: Convert the initial given temperature value from Celsius into the absolute Kelvin scale:

$$T_1 = 127^\circ\text{C} = 127 + 273 = 400 \text{ K}$$

Step 3: Use the problem's condition that the radiation rate doubles, meaning $E_2 = 2E_1$:

$$\frac{2E_1}{E_1} = \left(\frac{T_2}{400}\right)^4 \implies 2 = \left(\frac{T_2}{400}\right)^4$$

Step 4: Take the fourth root on both sides of the equation to solve for the final temperature T_2:

$$\frac{T_2}{400} = 2^{1/4} \implies T_2 = 400 \cdot 2^{1/4} \text{ K}$$

Step 5: Approximate the numerical value of $2^{1/4} \approx 1.1892$ to calculate the final absolute temperature:

$$T_2 = 400 \cdot 1.1892 \approx 475.68 \text{ K} \approx 476 \text{ K}$$

Final Answer: 476 K

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept: When capacitors are connected in a series configuration, the reciprocal of the total equivalent capacitance is equal to the sum of the reciprocals of the individual capacitances: $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$.

Solution: Step 1: Note the given values for the three identical capacitors connected in series:

$$C_1 = C_2 = C_3 = 9 \text{ pF}$$

Step 2: State the standard reciprocal formula for equivalent series capacitance:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Step 3: Substitute the identical component values into the series combination equation:

$$\frac{1}{C_{eq}} = \frac{1}{9} + \frac{1}{9} + \frac{1}{9} = \frac{3}{9}$$

Step 4: Simplify the fraction on the right-hand side of the equation:

$$\frac{1}{C_{eq}} = \frac{1}{3}$$

Step 5: Take the reciprocal of both sides to isolate the net equivalent capacitance value:

$$C_{eq} = 3 \text{ pF}$$

Final Answer: 3 pF

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept: The magnitude of the magnetic field B at the center of a circular coil consisting of N closely wound turns carrying a steady current I is given by the Biot-Savart derived formula $B = \frac{\mu_0 N I}{2R}$.

Solution: Step 1: Convert all the given physical parameter values into standard metric SI units:

$$\text{Number of turns } N = 100, \quad \text{Radius } R = 10 \text{ cm} = 0.1 \text{ m}, \quad \text{Current } I = 0.40 \text{ A}$$

Step 2: State the formula for the central magnetic field of a circular current-carrying coil:

$$B = \frac{\mu_0 N I}{2R}$$

Step 3: Substitute the standard constant values ($\mu_0 = 4\pi \times 10^{-7}$ T · m/A) into the expression:

$$B = \frac{(4\pi \times 10^{-7}) \cdot 100 \cdot 0.40}{2 \cdot 0.1}$$

Step 4: Simplify the arithmetic expression by combining numbers in the numerator and denominator:

$$B = \frac{4\pi \times 10^{-7} \cdot 40}{0.2} = \frac{160\pi \times 10^{-7}}{0.2} = 800\pi \times 10^{-7} \text{ T}$$

Step 5: Use the approximation $\pi \approx 3.1416$ to find the final numerical value in standard scientific notation:

$$B = 800 \cdot 3.1416 \times 10^{-7} = 2513.2 \times 10^{-7} \text{ T} \approx 2.5 \times 10^{-4} \text{ T}$$

Final Answer: 2.5×10^{-4} T

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept: The speed of a transverse wave traveling along a stretched string or rope depends on the tension T and the linear mass density μ (mass per unit length), given by the equation $v = \sqrt{\frac{T}{\mu}}$.

Solution: Step 1: Write down the functional relationship for the speed of a transverse wave on a string:

$$v = \sqrt{\frac{T}{\mu}}$$

Step 2: Analyze the tension in a heavy vertical rope hanging under its own weight. Let x be the distance from the free lower end of the rope.

Step 3: The tension at any point at a distance x from the bottom is solely due to the weight of the segment hanging below it:

$$T(x) = (\mu x) \cdot g$$

Step 4: Substitute this position-dependent tension expression back into the velocity equation:

$$v(x) = \sqrt{\frac{\mu x g}{\mu}} = \sqrt{gx}$$

Step 5: Examine the derived function $v(x) = \sqrt{gx}$. As the wave pulse moves upward, x increases, which means the speed v increases as it travels up the rope.

Final Answer: increases as it moves upward.

Answer: (C)

Go Back to Question 32

Q33.

Solution

Concept: The direction of the resultant of two vectors is given by the angle α it makes with a reference vector. For the direction to remain unchanged when the vector magnitudes are altered, the scaling ratio of the components must remain constant.

Solution: Step 1: Let the two initial forces be $F_1 = F$ and $F_2 = 2F$, acting at an arbitrary angle θ relative to each other.

Step 2: Express the mathematical tangent of the angle α that the resultant makes with the first force vector F_1:

$$\tan\alpha = \frac{F_2\sin\theta}{F_1 + F_2\cos\theta} = \frac{2F\sin\theta}{F + 2F\cos\theta} = \frac{2\sin\theta}{1 + 2\cos\theta}$$

Step 3: Write down the expressions for the modified forces as described in the problem statement:

$$F_1' = 2F \quad \text{and} \quad F_2' = 2F + 20$$

Step 4: Set up the tangent expression for the new configuration with angle α':

$$\tan\alpha' = \frac{F_2'\sin\theta}{F_1' + F_2'\cos\theta} = \frac{(2F + 20)\sin\theta}{2F + (2F + 20)\cos\theta}$$

Step 5: Since the direction remains unaltered, set $\tan\alpha = \tan\alpha'$ and solve for F:

$$\frac{2F + 20}{2F} = \frac{2F}{F} \implies \frac{2F + 20}{2F} = 2 \implies 2F + 20 = 4F \implies 2F = 20 \implies F = 10\,\text{N}$$

Final Answer: $\boxed{10\text{ N}}$

Answer: (A)

Go Back to Question 33

Q34.

Solution

Concept: In an intrinsic or pure semiconductor, the valence band is completely filled and the conduction band is completely empty at absolute zero. Thermal energy allows electrons to cross the energy band gap.

Solution: Step 1: Understand that electrical conductivity (σ) depends directly on the concentration of available charge carriers (free electrons and holes).

Step 2: Analyze the effect of a temperature increase on a pure semiconductor crystal lattice. Thermal energy breaks covalent bonds.

Step 3: As covalent bonds break, valence electrons absorb energy and jump across the forbidden energy gap (E_g) into the conduction band, leaving behind holes in the valence band.

Step 4: The number of charge carriers increases exponentially with temperature according to the relation:

$$n_i \propto e^{-\frac{E_g}{2k_B T}}$$

Step 5: Since the number of charge carriers increases significantly, the electrical conductivity of the material increases as the temperature rises.

Final Answer: increases

Answer: (B)

Go Back to Question 34

Q35.

Solution

Concept: The focal length of a lens is determined by the refractive index of its material relative to the surrounding medium, as expressed by the Lens Maker's Formula: $\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

Solution: Step 1: Write down the Lens Maker's Formula for the convex lens when it is surrounded by air ($\mu_{\text{air}} = 1$):

$$\frac{1}{f_a} = (\mu_g - 1) \cdot \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Step 2: Substitute the given numerical values for air focal length ($f_a = 20$ cm) and glass index ($\mu_g = 3/2$):

$$\frac{1}{20} = \left(\frac{3}{2} - 1\right) \cdot \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{2} \cdot \left(\frac{1}{R_1} - \frac{1}{R_2}\right) \implies \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{2}{20} = \frac{1}{10}$$

Step 3: Write down the Lens Maker's Formula for the lens immersed in water ($\mu_w = 4/3$):

$$\frac{1}{f_w} = \left(\frac{\mu_g}{\mu_w} - 1\right) \cdot \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Step 4: Substitute the relative refractive index values into the water immersion equation:

$$\frac{1}{f_w} = \left(\frac{3/2}{4/3} - 1\right) \cdot \frac{1}{10} = \left(\frac{9}{8} - 1\right) \cdot \frac{1}{10} = \frac{1}{8} \cdot \frac{1}{10} = \frac{1}{80}$$

Step 5: Solve for the final focal length of the lens when submerged in the water medium:

$$f_w = 80 \text{ cm}$$

Final Answer: 80 cm

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept: The potential gradient (k) along a potentiometer wire is defined as the potential drop per unit length of the wire. It is calculated using the formula $k = \frac{V_w}{L}$, where V_w is the voltage drop across the wire.

Solution: Step 1: Identify the given electrical parameters of the potentiometer circuit loop:

$$\text{Total wire length } L = 10 \text{ m}, \quad \text{Wire resistance } R_w = 20\ \Omega$$

$$\text{Battery EMF } E = 3 \text{ V}, \quad \text{Internal resistance } r = 0\ \Omega$$

Step 2: Calculate the steady electric current flowing through the potentiometer circuit wire using Ohm's Law:

$$I = \frac{E}{R_w + r} = \frac{3}{20 + 0} = 0.15 \text{ A}$$

Step 3: Determine the specific potential difference drop (V_w) developed across the ends of the wire:

$$V_w = I \cdot R_w = 0.15 \text{ A} \cdot 20\ \Omega = 3 \text{ V}$$

Step 4: Use the potential gradient definition formula to calculate the electric potential drop per meter:

$$k = \frac{V_w}{L}$$

Step 5: Substitute the values into the gradient equation to find the final numerical result:

$$k = \frac{3 \text{ V}}{10 \text{ m}} = 0.3 \text{ V/m}$$

Final Answer: 0.3 V/m

Answer: (A)

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Q37.

Solution

Concept: The escape velocity is the minimum speed required for a body to escape from the gravitational influence of a primary celestial body. It is derived by equating initial kinetic energy to total gravitational binding energy.

Solution: Step 1: Set up the energy conservation equation for a body of mass m launched from the Earth's surface with speed v_e:

$$\text{Total Initial Energy} = \text{Kinetic Energy} + \text{Potential Energy} = \frac{1}{2}mv_e^2 - \frac{GMm}{R}$$

Step 2: For the body to just escape to infinity, its total mechanical energy at minimum must equal zero:

$$\frac{1}{2}mv_e^2 - \frac{GMm}{R} = 0$$

Step 3: Rearrange the algebraic equation to solve for the escape velocity term:

$$\frac{1}{2}mv_e^2 = \frac{GMm}{R} \implies v_e^2 = \frac{2GM}{R} \implies v_e = \sqrt{\frac{2GM}{R}}$$

Step 4: Observe the final analytical expression for the escape velocity: $v_e = \sqrt{\frac{2GM}{R}}$. The mass of the projected body, m, cancels out entirely during algebraic simplification.
Step 5: Conclude that escape velocity is independent of the mass of the escaping body, which is mathematically represented as:

$$v_e \propto m^0$$

Final Answer: $\boxed{m^0}$

Answer: (A)

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Q38.

Solution

Concept: The thermal efficiency (η) of a perfectly reversible theoretical Carnot heat engine depends entirely on the absolute temperatures of the heat source (T_H) and the heat sink (T_C), given by $\eta = 1 - \frac{T_C}{T_H}$.

Solution: Step 1: Convert both operating temperatures from the given Celsius values into the absolute thermodynamic Kelvin scale:

$$\text{Source Temperature } T_H = 327^\circ\text{C} = 327 + 273 = 600 \text{ K}$$

$$\text{Sink Temperature } T_C = 27^\circ\text{C} = 27 + 273 = 300 \text{ K}$$

Step 2: State the standard efficiency mathematical formula for a Carnot thermal cycle:

$$\eta = 1 - \frac{T_C}{T_H}$$

Step 3: Substitute the absolute Kelvin temperature values into the efficiency equation:

$$\eta = 1 - \frac{300}{600}$$

Step 4: Simplify the fractional term and compute the decimal value of the engine efficiency:

$$\eta = 1 - \frac{1}{2} = \frac{1}{2} = 0.5$$

Step 5: Convert the decimal efficiency value into a percentage value by multiplying by 100:

$$\eta\% = 0.5 \times 100\% = 50\%$$

Final Answer: 50%

Answer: (A)

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Q39.

Solution

Concept: According to the de Broglie hypothesis, a moving particle has a wave nature. For an electron accelerated from rest through an electric potential difference V, its wavelength is given by $\lambda = \frac{h}{\sqrt{2meV}} \approx \frac{1.227}{\sqrt{V}}$ nm.

Solution: Step 1: State the specialized, simplified de Broglie wavelength formula for an electron accelerated by a voltage V:

$$\lambda = \frac{1.227}{\sqrt{V}} \text{ nm}$$

Step 2: Identify the value of the accelerating potential difference given in the problem:

$$V = 100 \text{ V}$$

Step 3: Substitute this potential value into the simplified de Broglie formula:

$$\lambda = \frac{1.227}{\sqrt{100}} \text{ nm}$$

Step 4: Compute the square root value in the denominator of the fraction:

$$\sqrt{100} = 10$$

Step 5: Perform the division to determine the final associated de Broglie wavelength:

$$\lambda = \frac{1.227}{10} \text{ nm} = 0.1227 \text{ nm} \approx 0.123 \text{ nm}$$

Final Answer: 0.123 nm

Answer: (B)

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Q40.

Solution

Concept: For an ideal transformer operating at 100% power efficiency, the electrical power delivered to the secondary coil is exactly equal to the power drawn by the primary coil ($V_p I_p = V_s I_s$). This gives the relationship $\frac{I_p}{I_s} = \frac{N_s}{N_p}$.

Solution: Step 1: State the relationship between the turns ratio and the coil currents for an ideal electrical transformer:

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

Step 2: Identify the given turns ratio and secondary load current parameters from the text:

$$\text{Turns ratio } \frac{N_p}{N_s} = \frac{1}{25} \implies \frac{N_s}{N_p} = 25$$

$$\text{Secondary current } I_s = 2 \text{ A}$$

Step 3: Rearrange the current relationship formula to isolate the unknown primary current variable I_p:

$$I_p = I_s \cdot \left(\frac{N_s}{N_p}\right)$$

Step 4: Substitute the given values into the rearranged primary current equation:

$$I_p = 2 \text{ A} \cdot 25$$

Step 5: Perform the simple scalar multiplication to find the final electric current value:

$$I_p = 50 \text{ A}$$

Final Answer: 50 A

Answer: (A)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	B	3	B	4	A	5	B
6	A	7	C	8	D	9	B	10	B
11	C	12	C	13	A	14	A	15	C
16	A	17	B	18	D	19	A	20	A
21	C	22	A	23	B	24	B	25	C
26	B	27	D	28	B	29	B	30	A
31	A	32	C	33	A	34	B	35	C
36	A	37	A	38	A	39	B	40	A