KIITEE Physics Sample Paper – 9

Duration: 50 Minutes **Maximum Marks: 160**

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct Answer), modelled on the Physics portion of **KIITEE** entrance.
- Each correct answer carries **+4 marks**. There is -1 **mark per wrong answer;** unattempted questions score **0**.
- Only **one** option is correct. Choose carefully.
- Syllabus level: **Class 11 & 12 (10+2) Physics — Mechanics,Heat & Thermodynamics, Electrodynamics, Optics and Modern Physics.**
- The test is computer based. Personal calculators, log tables, mobile phones, and other electronic gadgets are strictly prohibited.

Q1. A uniform solid cylinder of mass M and radius R is rolling down a rough inclined plane of inclination θ without slipping. The acceleration of the center of mass of the cylinder is:

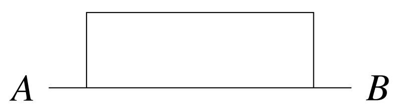
(A) $g \sin\theta$

(B) $\frac{2}{3}g \sin\theta$

(C) $\frac{1}{2}g \sin\theta$

(D) $\frac{3}{4}g \sin\theta$

Q2. In the circuit shown below, the equivalent resistance between terminals A and B is:



(A) $2\,\Omega$

(B) $4\,\Omega$

(C) $1\,\Omega$

(D) $3\,\Omega$

Q3. An ideal gas undergoes a thermodynamic process where its pressure varies with volume as $P = kV^2$, where k is a positive constant. If the volume of the gas increases from V_0 to $2V_0$, the work done by the gas is:

(A) $\frac{7}{3}kV_0^3$

(B) $3kV_0^3$

(C) $\frac{1}{3}kV_0^3$

(D) $\frac{8}{3}kV_0^3$

Q4. 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) $\frac{v_0^2}{a_0^2}$

Q5. The work function of a metal surface is 2.5 eV. If light of wavelength 300 nm is incident on the surface, the maximum kinetic energy of the emitted photoelectrons is closest to (take $hc = 1240\ \text{eV} \cdot \text{nm}$):

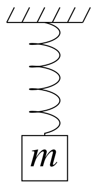
(A) 4.13 eV

(B) 1.63 eV

(C) 2.50 eV

(D) 0.85 eV

Q6. A block of mass m is suspended from a vertical spring of spring constant k as shown in the diagram. If the block is pulled down slightly from its equilibrium position and released, its time period of oscillation is:



(A) $2\pi\sqrt{\frac{m}{k}}$

(B) $2\pi\sqrt{\frac{2m}{k}}$

(C) $\pi\sqrt{\frac{m}{k}}$

(D) $2\pi\sqrt{\frac{k}{m}}$

Q7. A particle moves in a circle of radius $r = 2$ m with a constant tangential acceleration. If the velocity of the particle is 4 m/s at the end of the second revolution after motion has begun, the tangential acceleration is:

(A) $\frac{1}{\pi}$ m/s^2

(B) $\frac{2}{\pi}$ m/s^2

(C) $\frac{1}{2\pi}$ m/s^2

(D) $\frac{4}{\pi}$ m/s^2

Q8. Two infinite parallel plates are separated by a distance d and carry uniform surface charge densities $+\sigma$ and $-\sigma$ respectively. The electric field at a point between the plates is:

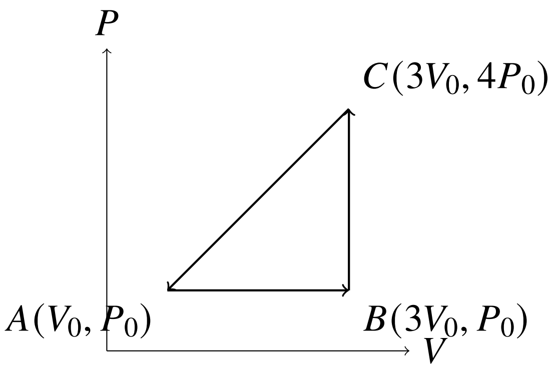
(A) zero

(B) $\frac{\sigma}{\epsilon_0}$

(C) $\frac{\sigma}{2\epsilon_0}$

(D) $\frac{2\sigma}{\epsilon_0}$

Q9. An ideal gas is taken through a cyclic process $ABCA$ as shown in the $P - V$ diagram. The net work done by the gas per cycle is:



(A) $3P_0V_0$

(B) $6P_0V_0$

(C) $4P_0V_0$

(D) $1.5P_0V_0$

Q10. A convex lens of focal length $f = 20$ cm forms a real image of an object. If the image distance is 30 cm from the optical center of the lens, the object distance from the lens is:

(A) -60 cm

(B) -30 cm

(C) -15 cm

(D) -12 cm

Q11. The binding energy per nucleon for a nucleus X_Z^A is maximum around which region of the mass number A?

(A) $A < 20$

(B) $A \approx 56$

(C) $A \approx 120$

(D) $A > 200$

Q12. A body of mass $m = 2$ kg is acted upon by a time-varying force $F = 6t$ (in Newtons). If the body starts from rest at $t = 0$, its velocity at $t = 3$ s is:

(A) 9 m/s

(B) 18 m/s

(C) 27 m/s

(D) 13.5 m/s

Q13. A current-carrying circular loop of radius R carries a steady current I. The magnetic field at the center of the loop is B_0. At what distance along the axis from the center of the loop will the magnetic field become $\frac{B_0}{8}$?

(A) $R\sqrt{3}$

(B) $R\sqrt{2}$

(C) $2R$

(D) $3R$

Q14. In a Young's double-slit experiment, the slit separation is $d = 0.2$ mm and the distance to the screen is $D = 1.0$ m. If light of wavelength $\lambda = 600$ nm is used, the fringe width observed on the screen is:

(A) 1.5 mm

(B) 3.0 mm

(C) 4.5 mm

(D) 6.0 mm

Q15. According to Bohr's model of the hydrogen atom, the radius of the electron's orbit in the ground state is r_0. The radius of the orbit in the second excited state $(n = 3)$ is:

(A) $3r_0$

(B) $4r_0$

(C) $9r_0$

(D) $16r_0$

Q16. A force $\vec{F} = (2\hat{i} + 3\hat{j} - \hat{k})$ N acts on a particle and displaces it from $\vec{r}_1 = (\hat{i} + \hat{j})$ m to $\vec{r}_2 = (2\hat{i} + 4\hat{j} + \hat{k})$ m. The work done by the force is:

(A) 10 J

(B) 12 J

(C) 8 J

(D) 14 J

Q17. A parallel plate capacitor is connected to a battery of voltage V. With the battery remaining connected, a dielectric slab of dielectric constant $K > 1$ is inserted between the plates. What happens to the charge Q on the plates and the electric field E between them?

(A) Q increases, E decreases

(B) Q increases, E remains constant

(C) Q remains constant, E decreases

(D) Q decreases, E remains constant

Q18. An alternating voltage source given by $v = 200\sqrt{2}\sin(100\pi t)$ V is connected across a pure resistor of resistance $R = 50\,\Omega$. The root-mean-square (rms) current in the circuit is:

(A) 2 A

(B) 4 A

(C) $2\sqrt{2}$ A

(D) $4\sqrt{2}$ A

Q19. The efficiency of a Carnot engine operating between temperatures $T_H = 600$ K and $T_C = 300$ K is:

(A) 25%

(B) 33.3%

(C) 50%

(D) 66.7%

Q20. A progressive wave is described by the equation $y(x,t) = 0.05\sin(10\pi t - 2\pi x)$, where x, y are in meters and t is in seconds. The wave speed is:

(A) 5 m/s

(B) 2 m/s

(C) 10 m/s

(D) 20 m/s

Q21. Identify the logic gate represented by the given truth table:

Input A	Input B	Output Y
0	0	1
0	1	1
1	0	1
1	1	0

(A) AND

(B) OR

(C) NAND

(D) NOR

Q22. A projectile is thrown from the ground with an initial velocity $\vec{u} = u_x\hat{i} + u_y\hat{j}$. If the range of the projectile is equal to its maximum height, then the angle of projection θ with the horizontal satisfies:

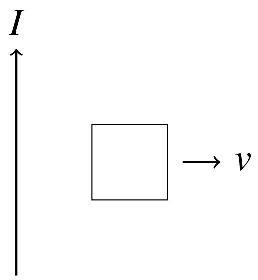
(A) $\tan\theta = 1$

(B) $\tan\theta = 2$

(C) $\tan\theta = 4$

(D) $\tan\theta = 0.5$

Q23. A straight long wire carries a steady current I. A square loop of wire is placed in the same plane as the wire, with two of its sides parallel to the long wire. If the loop is pulled away from the wire with a constant velocity v, the induced current in the loop is:



(A) Clockwise

(B) Counter-clockwise

(C) Zero

(D) Alternating

Q24. The temperature of a blackbody is doubled. The total radiant energy emitted per second by the body increases by a factor of:

(A) 2

(B) 4

(C) 8

(D) 16

Q25. An object is placed at a distance of 15 cm in front of a concave mirror of focal length 10 cm. The nature and magnification m of the image formed are:

(A) Real, $m = -2$

(B) Virtual, $m = +2$

(C) Real, $m = -0.5$

(D) Virtual, $m = +0.5$

Q26. The de Broglie wavelength of an electron accelerated through a potential difference of 100 V is approximately:

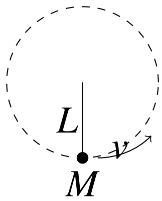
(A) 0.123 nm

(B) 1.23 nm

(C) 12.3 nm

(D) 0.012 nm

Q27. A mass M attached to a string of length L is rotated in a vertical circle. The minimum speed required at the lowest point of the circle so that the string does not go slack anywhere during the motion is:



(A) $\sqrt{gL}$
(B) $\sqrt{3gL}$
(C) $\sqrt{5gL}$
(D) $\sqrt{7gL}$

Q28. A galvanometer of resistance $50\,\Omega$ gives full-scale deflection for a current of 2 mA. To convert it into an ammeter capable of measuring currents up to 2 A, the resistance of the shunt to be connected in parallel is approximately:

(A) $0.05\,\Omega$
(B) $0.5\,\Omega$
(C) $5.0\,\Omega$
(D) $0.01\,\Omega$

Q29. When an unpolarized light beam of intensity I_0 passes through a single ideal polarizing sheet, the intensity of the transmitted light is:

(A) I_0
(B) $\frac{I_0}{2}$
(C) $\frac{I_0}{4}$
(D) Zero

Q30. The radioactive decay of a certain sample has a half-life of 10 days. The time taken for $\frac{7}{8}$th of the initial sample to decay is:

(A) 20 days

(B) 30 days

(C) 40 days

(D) 15 days

Q31. A thin uniform rod of mass m and length l has a moment of inertia I_1 about an axis passing through its center and perpendicular to its length. Its moment of inertia about a parallel axis passing through one of its ends is I_2. The ratio $\frac{I_2}{I_1}$ is:

(A) 2

(B) 3

(C) 4

(D) 1.5

Q32. Three capacitors of capacitances $2\,\mu$F, $3\,\mu$F, and $6\,\mu$F are connected in series across a 12 V battery. The charge on the $3\,\mu$F capacitor is:

(A) $12\,\mu$C

(B) $36\,\mu$C

(C) $4\,\mu$C

(D) $18\,\mu$C

Q33. A critical angle for a medium with respect to air is 30°. The refractive index of the medium is:

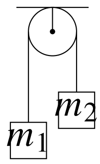
(A) 1.5

(B) 2.0

(C) $\sqrt{2}$

(D) $\sqrt{3}$

Q34. Two masses $m_1 = 4$ kg and $m_2 = 1$ kg are connected by a light string passing over a smooth frictionless pulley as shown. The acceleration of the system when released from rest is (take $g = 10$ m/s^2):



(A) 6 m/s^2

(B) 8 m/s^2

(C) 5 m/s^2

(D) 4 m/s^2

Q35. A magnetic dipole of magnetic moment $\vec{M}$ is placed in a uniform magnetic field $\vec{B}$. The potential energy of the dipole is minimum when the angle between $\vec{M}$ and $\vec{B}$ is:

(A) 0°

(B) 90°

(C) 180°

(D) 45°

Q36. The escape velocity from the surface of a planet of mass M and radius R is v_e. If another planet has twice the mass and half the radius of this planet, the escape velocity from its surface will be:

(A) v_e

(B) $2v_e$

(C) $\sqrt{2}v_e$

(D) $4v_e$

Q37. In a step-up transformer, the turns ratio is 1 : 10. If the primary voltage is 220 V and primary current is 5 A, assuming 100% efficiency, the current in the secondary coil is:

(A) 50 A

(B) 0.5 A

(C) 2.5 A

(D) 0.25 A

Q38. Two simple harmonic motions are represented by $y_1 = 5\sin(2\pi t)$ and $y_2 = 5\sin(2\pi t + \frac{\pi}{3})$. The amplitude of the resultant motion obtained by their superposition is:

(A) 5

(B) $5\sqrt{2}$

(C) $5\sqrt{3}$

(D) 10

Q39. An intrinsic semiconductor has a bandgap energy of 1.1 eV. As the temperature increases, its electrical conductivity:

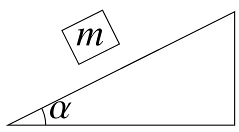
(A) Increases exponentially

(B) Decreases linearly

(C) Remains completely unchanged

(D) Decreases exponentially

Q40. A block of mass m is sliding down a rough inclined plane of inclination α at a constant velocity. The coefficient of kinetic friction between the block and the plane is:



(A) $\sin\alpha$

(B) $\cos\alpha$

(C) $\tan\alpha$

(D) $\cot\alpha$

Detailed Solutions

Q1.

Solution

Concept:
When a body rolls down an inclined plane without slipping, both its translational inertia and rotational inertia govern its movement. The acceleration depends on the angle of the incline and the distribution of the mass of the rolling body, which is characterized by its moment of inertia about the central axis.

Solution:

(a) For a uniform solid cylinder of mass M and radius R, the moment of inertia about its central longitudinal axis is given by the formula $I = \frac{1}{2}MR^2$.

(b) The general equation for the acceleration of a body rolling down an inclined plane of inclination θ without slipping is $a = \frac{g \sin \theta}{1 + \frac{I}{MR^2}}$.

(c) Substituting the value of I for the solid cylinder into the acceleration formula yields $a = \frac{g \sin \theta}{1 + \frac{\frac{1}{2}MR^2}{MR^2}}$.

(d) Simplifying the denominator gives $1 + \frac{1}{2} = \frac{3}{2}$. Substituting this value back into the equation results in $a = \frac{g \sin \theta}{\frac{3}{2}}$.

(e) Rearranging the expression gives a final acceleration of $a = \frac{2}{3} g \sin \theta$. This corresponds to option (B).

Final Answer: $2_{\overline{3g \sin \theta}}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept:
To find the equivalent resistance between two terminals in an electrical circuit, look for components that are connected in series or in parallel combination. Elements in series share the same current, while elements connected in parallel branches share the exact same potential difference across their terminals.

Solution:

(a) Analyze the lower branch of the circuit connecting terminal A to terminal B. Two resistors, each having a resistance of $2\,\Omega$, are connected sequentially one after the other.

(b) Since these two resistors are connected in series, their individual resistance values add up directly, giving a combined lower branch resistance of $R_{\text{lower}} = 2\,\Omega + 2\,\Omega = 4\,\Omega$.

(c) Now look at the upper branch of the circuit, which contains a single resistor of $4\,\Omega$ connected across the same junction nodes.

(d) The equivalent $4\,\Omega$ resistance of the lower branch and the $4\,\Omega$ resistor of the upper branch are connected in parallel between terminals A and B.

(e) The equivalent resistance is calculated as $R_{AB} = \frac{4\times4}{4+4} = \frac{16}{8} = 2\,\Omega$. This matches option (A).

Final Answer: $2\,\Omega$

Answer: (A)

Go Back to Question 2

Q3.

Solution

Concept:

Work done by an ideal gas during a thermodynamic process involving volume changes is computed by integrating the pressure with respect to volume over the specified boundaries. This relationship represents the area under the process curve on a standard pressure-volume diagram.

Solution:

(a) The pressure is given as a function of volume by the relation $P = kV^2$. The work done W during a volume change is given by the integral $\int P\,dV$.

(b) Set the lower limit of integration to the initial volume V_0 and the upper limit to the final expanded volume $2V_0$.

(c) Substitute the expression for pressure into the integral to get $W = \int_{V_0}^{2V_0} kV^2\,dV$.

(d) Pull the positive constant k out of the integration and evaluate the remaining term to get $W = k\left[\frac{V^3}{3}\right]_{V_0}^{2V_0}$.

(e) Substitute the upper and lower limits to find $W = \frac{k}{3}\left[(2V_0)^3 - V_0^3\right] = \frac{k}{3}[8V_0^3 - V_0^3] = \frac{7}{3}kV_0^3$. This corresponds to option (A).

Final Answer: $7\frac{}{3kV_0^3}$

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept:
In simple harmonic motion, a particle moves periodically along a straight line. Its kinematic variables, such as displacement, velocity, and acceleration, vary sinusoidally over time, and their maximum amplitudes depend entirely on the angular frequency and maximum displacement of the oscillation.

Solution:

(a) Let the amplitude of the simple harmonic motion be A and its angular frequency be ω. The maximum velocity occurs at the equilibrium position.

(b) The formula for the maximum velocity is given by $v_0 = \omega A$. Squaring this expression gives $v_0^2 = \omega^2 A^2$.

(c) The maximum acceleration occurs at the extreme positions of the oscillation and its magnitude is given by the expression $a_0 = \omega^2 A$.

(d) To eliminate the angular frequency ω from the equations, divide the squared maximum velocity by the maximum acceleration.

(e) Performing the division gives $\frac{v_0^2}{a_0} = \frac{\omega^2 A^2}{\omega^2 A} = A$. Therefore, the amplitude is $\frac{v_0^2}{a_0}$, which corresponds to option (A).

Final Answer: $v_0^2 \overline{a_0}$

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:
The photoelectric effect is described quantitatively by Einstein's photoelectric equation. Incoming photons deliver packets of energy to electrons in a metal, and the excess energy after overcoming the surface work function is converted into the kinetic energy of the emitted photoelectrons.

Solution:

(a) Einstein's photoelectric equation states that the maximum kinetic energy of the emitted photoelectrons is given by $K_{\max} = E - \phi$, where E is photon energy and ϕ is the work function.

(b) The energy of the incident photon can be calculated using its wavelength with the relationship $E = \frac{hc}{\lambda}$.

(c) Substituting the given values $hc = 1240$ eV·nm and $\lambda = 300$ nm gives $E = \frac{1240}{300} = 4.133$ eV.

(d) Now substitute the calculated photon energy and the given work function $\phi = 2.5$ eV back into the maximum kinetic energy equation.

(e) This yields $K_{\max} = 4.133 \text{ eV} - 2.5 \text{ eV} = 1.633 \text{ eV}$. Therefore, the maximum kinetic energy is closest to 1.633 eV, matching option (B).

Final Answer: 1.63 eV

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:

A mass-spring system oscillating vertically undergoes simple harmonic motion. The restoring force responsible for the oscillation is provided by the spring elongation and depends linearly on the spring stiffness constant, creating a periodic cycle independent of the gravitational field strength.

Solution:

(a) When a block of mass m is suspended vertically from a spring of constant k, it stretches the spring to an equilibrium position where gravity balances the spring force.

(b) Displacing the block slightly from this position creates a linear restoring force described by Hooke's Law, $F = -kx$.

(c) Applying Newton's second law gives $m\frac{d^2x}{dt^2} + kx = 0$, which is the differential equation for a simple harmonic oscillator.

(d) The angular frequency of this simple harmonic motion is given by the standard formula $\omega = \sqrt{\frac{k}{m}}$.

(e) The time period of oscillation T is related to angular frequency by $T = \frac{2\pi}{\omega}$. Substituting ω yields $T = 2\pi\sqrt{\frac{m}{k}}$, which is option (A).

Final Answer: $2\pi\sqrt{\frac{m}{k}}$

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept:

For a particle moving in a circular path with constant tangential acceleration, its linear kinematic relationships along the circular arc are analogous to one-dimensional motion with uniform acceleration. The total distance traveled can be expressed in terms of the number of full revolutions.

Solution:

(a) The particle starts from rest, so its initial linear velocity $u = 0$. The final linear velocity after two full revolutions is $v = 4$ m/s.

(b) One complete revolution around a circle of radius r corresponds to a distance of $2\pi r$. Therefore, two revolutions cover a total distance of $s = 2 \times 2\pi r = 4\pi r$.

(c) Given that the radius $r = 2$ m, the total linear distance traveled along the arc is $s = 4\pi \times 2 = 8\pi$ m.

(d) Use the third kinematic equation of motion, $v^2 = u^2 + 2a_t s$, where a_t represents the constant tangential acceleration.

(e) Substitute the known values: $4^2 = 0^2 + 2 \times a_t \times 8\pi$, which simplifies to $16 = 16\pi a_t$. Solving for a_t gives $\frac{1}{\pi}$ m/s^2, matching option (A).

Final Answer: $1\frac{}{\pi \text{ m/s}^2}$

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept:
The electric field produced by an infinite plane sheet of uniform charge density is constant in magnitude and directed perpendicularly away from or toward the sheet. When two such plates are brought close together, their individual electric fields superimpose constructively or destructively depending on the region.

Solution:

(a) An infinite parallel plate with a uniform positive surface charge density $+\sigma$ creates a uniform electric field directed normally outward with a magnitude of $E_1 = \frac{\sigma}{2\epsilon_0}$.

(b) Similarly, the plate carrying a negative surface charge density $-\sigma$ produces a uniform electric field directed normally inward with a magnitude of $E_2 = \frac{\sigma}{2\epsilon_0}$.

(c) Consider a point located in the space directly between the two parallel plates. Here, the field from the positive plate points away from it, toward the negative plate.

(d) The field from the negative plate points toward itself, which is the exact same direction as the field from the positive plate.

(e) Since both fields point in the same direction, they add together constructively: $E = E_1 + E_2 = \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0}$. This matches option (B).

Final Answer: $\sigma \frac{}{\epsilon_0}$

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:
On a pressure-volume diagram, the net work done by an ideal gas undergoing a closed cyclic thermodynamic process is equal to the area enclosed by the path of the cycle. The sign of the work depends on the direction of the cycle.
Solution:

(a) The cyclic process $ABCA$ forms a right-angled triangle on the pressure-volume indicator diagram, with its vertices clearly defined by the coordinate points.

(b) The base of this triangle lies along the constant pressure line AB and its length represents the change in volume, $\Delta V = 3V_0 - V_0 = 2V_0$.

(c) The height of the triangle lies along the constant volume line BC and its length represents the change in pressure, $\Delta P = 4P_0 - P_0 = 3P_0$.

(d) The area of a right-angled triangle is given by the formula Area $= \frac{1}{2} \times \text{base} \times \text{height}$.

(e) Substituting the values gives Work $= \frac{1}{2} \times (2V_0) \times (3P_0) = 3P_0V_0$. Since the cycle is clockwise, the net work is positive, matching option (A).

Final Answer: $3\ \mathrm{P}_0V_0$

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept:
The position of an object and its corresponding image formed by a thin spherical lens are mathematically related by the thin lens formula. Standard Cartesian sign conventions must be applied to the focal length, object distance, and image distance values.

Solution:

(a) According to the sign convention for a convex lens forming a real image, the focal length is positive ($f = +20$ cm) and the image distance is positive ($v = +30$ cm).

(b) The thin lens formula relates these values to the object distance u through the equation $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$.

(c) Rearranging the lens formula to isolate the object distance term gives the expression $\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$.

(d) Substitute the given values into the equation to obtain $\frac{1}{u} = \frac{1}{30} - \frac{1}{20}$. Finding a common denominator yields $\frac{1}{u} = \frac{2-3}{60} = -\frac{1}{60}$.

(e) Taking the reciprocal gives $u = -60$ cm. The negative sign confirms the object is placed in front of the lens, matching option (A).

Final Answer: -60 cm

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept:
The stability of an atomic nucleus is quantitatively measured by its binding energy per nucleon, which represents the average energy required to remove a single nucleon from the core. This value varies across different mass numbers and dictates whether a particular nucleus prefers nuclear fusion or nuclear fission.

Solution:

(a) The binding energy per nucleon curve shows how nuclear stability varies as a function of the total mass number A.

(b) For very light nuclei where the mass number A is less than 20, the binding energy per nucleon is relatively low because surface nucleons lack a full set of neighbors.

(c) As the mass number increases, the short-range attractive strong nuclear force acts on more nucleons, causing the curve to rise steadily toward a peak.

(d) This prominent peak represents the maximum nuclear stability and occurs precisely in the intermediate mass region where the mass number $A \approx 56$, corresponding to Iron-56.

(e) Beyond this peak value, the long-range electrostatic repulsive force between protons grows faster than the strong force, causing a gradual decline in binding energy for heavier elements.

Final Answer: A $\approx$ 56

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:
When a body is subjected to a time-dependent variable force, its resulting linear acceleration is also a function of time. The change in velocity over a specific period is found by integrating this acceleration equation with respect to time over the given interval.

Solution:

(a) According to Newton's second law of motion, force equals mass times acceleration, which can be rearranged to state that acceleration is $a = \frac{F}{m}$.

(b) Substituting the given values of the time-varying force $F = 6t$ and the mass $m = 2$ kg yields the acceleration function $a = \frac{6t}{2} = 3t$.

(c) Acceleration is defined as the time rate of change of velocity, which gives the fundamental calculus relationship $\frac{dv}{dt} = 3t$, or $dv = 3t\,dt$.

(d) Integrate both sides of this differential equation, applying the lower limit of rest condition $v = 0$ at $t = 0$ and the upper limit v at $t = 3$ s.

(e) Evaluating the integral gives $v = \int_0^3 3t\,dt = \left[\frac{3t^2}{2}\right]_0^3 = \frac{3\times3^2}{2} - 0 = \frac{27}{2} = 13.5$ m/s.

Final Answer: 13.5 m/s

Answer: (D)

Go Back to Question 12

Q13.

Solution

Concept:

The magnetic field produced by a circular current-carrying loop is maximum at its geometric center and decreases gradually as one moves along its central axis. The field profile depends directly on the loop radius and the axial distance from the center.

Solution:

(a) The magnetic field at the center of a circular loop carrying current I is given by the expression $B_0 = \frac{\mu_0 I}{2R}$.

(b) The magnetic field at a perpendicular distance x along the central axis from the center of the loop is given by $B = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$.

(c) Expressing the axial field equation in terms of the central magnetic field simplifies the formula to $B = B_0 \left(\frac{R^2}{R^2+x^2}\right)^{3/2}$.

(d) We are looking for the distance x where the magnetic field becomes $B = \frac{B_0}{8}$. Substituting this value gives $\frac{1}{8} = \left(\frac{R^2}{R^2+x^2}\right)^{3/2}$.

(e) Taking the two-thirds power of both sides simplifies the equation to $\frac{1}{4} = \frac{R^2}{R^2+x^2}$. Cross-multiplying yields $R^2 + x^2 = 4R^2$, which means $x^2 = 3R^2$ or $x = R\sqrt{3}$.

Final Answer: R$\sqrt{3}$

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept:
In Young's double-slit experiment, coherent light waves emerging from two narrow slits interfere with each other to produce an alternating pattern of bright and dark bands. The spacing between consecutive bright or dark fringes is determined by the configuration geometry.

Solution:

(a) The formula for the fringe width β in a standard double-slit setup is given by $\beta = \frac{\lambda D}{d}$, where D is the screen distance and d is the slit separation.

(b) Write down all given parameters in standard SI units: wavelength $\lambda = 600$ nm $= 600 \times 10^{-9}$ m, distance $D = 1.0$ m, and separation $d = 0.2$ mm $= 0.2 \times 10^{-3}$ m.

(c) Substitute these values directly into the fringe width equation to get $\beta = \frac{600 \times 10^{-9} \times 1.0}{0.2 \times 10^{-3}}$.

(d) Simplifying the numbers gives $\beta = \frac{6 \times 10^{-7}}{2 \times 10^{-4}} = 3 \times 10^{-3}$ m.

(e) Converting this meter value back into millimeters yields a final fringe width value of 3.0 mm.

Final Answer: 3.0 mm

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept:
According to Bohr's model of the hydrogen atom, electrons revolve around the central nucleus only in certain allowed, non-radiating circular orbits. The physical radius of these quantized stationary states depends on the principal quantum number.
Solution:

(a) Bohr's quantization condition for angular momentum leads to an explicit relationship where the radius of the electron orbit is directly proportional to the square of the principal quantum number n^2.

(b) The mathematical formula for the radius of the n-th permissible orbit in a hydrogen atom is given by $r_n = n^2 r_0$, where r_0 is the ground-state Bohr radius.

(c) The lowest energy level is the ground state, which corresponds to a principal quantum number of $n = 1$, giving a radius of $r_1 = 1^2 r_0 = r_0$.

(d) The first excited state corresponds to $n = 2$, and the second excited state corresponds to a principal quantum number of $n = 3$.

(e) Substituting $n = 3$ into the orbit radius formula yields $r_3 = 3^2 r_0 = 9r_0$.

Final Answer: $9\mathrm{r}_0$

Answer: (C)

Go Back to Question 15

Q16.

Solution

Concept:
The work done by a constant vector force during a physical displacement is calculated by taking the scalar dot product of the force vector and the overall displacement vector. This mathematical operation multiplies parallel components to yield a scalar energy value.
Solution:

(a) The net linear displacement vector $\vec{\Delta r}$ of the particle is found by subtracting the initial position vector from the final position vector, giving $\vec{\Delta r} = \vec{r}_2 - \vec{r}_1$.

(b) Substituting the given vectors yields $\vec{\Delta r} = (2\hat{i}+4\hat{j}+\hat{k})-(\hat{i}+\hat{j}) = (2-1)\hat{i}+(4-1)\hat{j}+(1-0)\hat{k} = \hat{i} + 3\hat{j} + \hat{k}$.

(c) The work done W by a constant force is defined by the dot product formula $W = \vec{F} \cdot \vec{\Delta r}$.

(d) Substitute the force vector $\vec{F} = 2\hat{i} + 3\hat{j} - \hat{k}$ and the computed displacement vector into the dot product formula.

(e) Multiplying corresponding spatial components yields $W = (2 \times 1) + (3 \times 3) + (-1 \times 1) = 2 + 9 - 1 = 10$ J.

Final Answer: 10 J

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept:
When a dielectric slab is inserted into a parallel plate capacitor, it alters the electrical environment between the plates. The final outcomes for charge and electric field depend strictly on whether the system remains connected to a constant voltage source.

Solution:

(a) Because the capacitor remains connected to the battery throughout the process, the potential difference across the plates is held constant at the original voltage value V.

(b) The electric field between parallel plates depends directly on the voltage and separation according to the relation $E = \frac{V}{d}$. Since both V and d are unchanged, the electric field E remains constant.

(c) Inserting a dielectric material with a dielectric constant $K > 1$ increases the capacitance from its original value C_0 to a new value $C = KC_0$.

(d) The total charge stored on the plates is determined by the capacitance formula $Q = CV$.

(e) Substituting the new capacitance value gives $Q = (KC_0)V = KQ_0$. Since $K > 1$, the stored charge Q increases while the electric field remains constant.

Final Answer: Q increases, E remains constant

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept:
An alternating voltage source produces a sinusoidally varying electrical signal. The root-mean-square current in a purely resistive alternating current circuit represents the effective direct current equivalent and is determined using Ohm's law with the root-mean-square voltage value.
Solution:

(a) The given time-dependent alternating voltage source equation has the standard mathematical form $v = v_0 \sin(\omega t)$, where v_0 is the peak voltage.

(b) Comparing the given expression $v = 200\sqrt{2}\sin(100\pi t)$ V with the standard form reveals that the peak voltage value is $v_0 = 200\sqrt{2}$ V.

(c) The root-mean-square voltage V_{rms} is related to the peak voltage by the definition $V_{\text{rms}} = \frac{v_0}{\sqrt{2}}$.

(d) Substituting the peak value gives $V_{\text{rms}} = \frac{200\sqrt{2}}{\sqrt{2}} = 200$ V.

(e) According to Ohm's law for a purely resistive circuit, the root-mean-square current is $I_{\text{rms}} = \frac{V_{\text{rms}}}{R} = \frac{200}{50} = 4$ A.

Final Answer: 4 A

Answer: (B)

Go Back to Question 18

Q19.

Solution

Concept:
A Carnot engine is a theoretical idealized thermodynamic cycle that operates at maximum possible efficiency between two constant temperature reservoirs. Its thermal efficiency is limited solely by the absolute temperatures of these hot and cold reservoirs.

Solution:

(a) The efficiency η of a reversible Carnot heat engine is defined mathematically by the temperature formula $\eta = 1 - \frac{T_C}{T_H}$, where temperatures must be expressed on the absolute Kelvin scale.

(b) Identify the given thermodynamic parameters from the problem: the hot source temperature is $T_H = 600$ K and the cold sink temperature is $T_C = 300$ K.

(c) Substitute these absolute temperature values directly into the efficiency equation to obtain $\eta = 1 - \frac{300}{600}$.

(d) Simplifying the fraction gives $\eta = 1 - 0.5 = 0.5$.

(e) To express this fractional efficiency value as a standard percentage, multiply by 100, which gives $\eta = 0.5 \times 100\% = 50\%$.

Final Answer: 50%

Answer: (C)

Go Back to Question 19

Q20.

Solution

Concept:
A continuous progressive wave traveling through a medium can be represented mathematically by a sinusoidal wave function. The physical speed at which the wave profile propagates forward is determined by its temporal angular frequency and its spatial wave number.

Solution:

(a) The given mathematical equation for the progressive wave is $y(x,t) = 0.05\sin(10\pi t - 2\pi x)$.

(b) The standard formula for a progressive wave traveling along the positive x-direction is $y(x,t) = A\sin(\omega t - kx)$.

(c) Comparing the coefficients of the given wave function with the standard equation allows us to find the angular frequency $\omega = 10\pi$ rad/s.

(d) Similarly, matching the spatial terms yields the value for the wave number, which is $k = 2\pi$ rad/m.

(e) The propagation speed v of the wave is given by the ratio of its angular frequency to its wave number, $v = \frac{\omega}{k} = \frac{10\pi}{2\pi} = 5$ m/s.

Final Answer: 5 m/s

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept:
A logic gate is an idealized model of computation that implements a Boolean function on one or more binary inputs to produce a single binary output. The relationship between these electrical input combinations and the resulting output state is summarized comprehensively in a truth table.
Solution:

(a) Examine the outputs given in the truth table for each binary input pairs. The output Y is equal to 1 for the combinations $(0, 0)$, $(0, 1)$, and $(1, 0)$.

(b) The output drops to 0 only when both inputs A and B are simultaneously equal to 1.

(c) Recall that a standard AND gate produces an output of 1 if and only if both inputs are 1, yielding outputs of 0, 0, 0, and 1 respectively for the given table rows.

(d) A NOT-AND or NAND gate acts as an inverted AND gate, which mathematically complements the outputs of a standard AND operation.

(e) Applying a logical NOT to the AND gate outputs transforms the sequence $(0, 0, 0, 1)$ into $(1, 1, 1, 0)$, which perfectly matches the values given in the question table.

Final Answer: NAND

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept:
A projectile launched from the ground into a uniform gravitational field follows a curved parabolic trajectory. Its flight parameters, such as the maximum vertical height achieved and the total horizontal range covered, are uniquely dictated by the initial launch speed and the angle of inclination with the horizontal.
Solution:

(a) Let the initial velocity be u and the launch angle be θ. The mathematical formula for the maximum height H reached by a projectile is given by $H = \frac{u^2 \sin^2\theta}{2g}$.

(b) The mathematical formula for the horizontal range R covered by the projectile during its complete flight time is given by the expression $R = \frac{u^2 \sin(2\theta)}{g}$.

(c) Using the trigonometric double-angle identity, the expression for the horizontal range can be rewritten in an expanded form as $R = \frac{2u^2 \sin\theta \cos\theta}{g}$.

(d) The problem states that the horizontal range is exactly equal to the maximum height. Setting these two expressions equal to each other gives $\frac{2u^2 \sin\theta \cos\theta}{g} = \frac{u^2 \sin^2\theta}{2g}$.

(e) Canceling the common terms u^2, g, and one factor of $\sin\theta$ from both sides simplifies the equation to $2\cos\theta = \frac{\sin\theta}{2}$, which rearranges directly to $\tan\theta = 4$.

Final Answer: $\tan\theta = 4$

Answer: (C)

Go Back to Question 22

Q23.

Solution

Concept:
According to Faraday's law of electromagnetic induction and Lenz's law, a change in the magnetic flux passing through a closed conducting loop induces an electromotive force. This induced voltage creates a current whose magnetic field opposes the original change in flux.
Solution:

(a) A long straight vertical wire carrying a steady upward current I produces a non-uniform magnetic field directed into the plane of the page on its right side.

(b) The strength of this magnetic field decreases as the perpendicular distance from the wire increases, according to Ampere's law.

(c) When the square conducting loop is pulled away from the wire with a constant horizontal velocity v, it moves into regions of progressively weaker magnetic field lines.

(d) Because the field weakens as distance grows, the total magnetic flux directed into the plane of the page through the area of the loop is continuously decreasing over time.

(e) To oppose this decrease in downward flux, Lenz's law dictates that the induced current must generate its own magnetic field pointing into the page. According to the right-hand rule, this requires a clockwise current loop.

Final Answer: Clockwise

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept:
The total energy radiated per unit surface area per unit time by an ideal blackbody is governed by the Stefan-Boltzmann law. This fundamental thermodynamic principle states that the total emissive power is directly proportional to the fourth power of the absolute temperature.

Solution:

(a) Let the initial absolute temperature of the blackbody be T_1 and its initial radiant energy emitted per second be E_1. According to the Stefan-Boltzmann law, $E_1 = \sigma A T_1^4$.

(b) The problem states that the temperature of the blackbody is doubled, which means the new absolute temperature can be written as $T_2 = 2T_1$.

(c) The new radiant energy emitted per second by the same blackbody can be expressed using the same proportional relationship as $E_2 = \sigma A T_2^4$.

(d) Substituting the new temperature expression into the second formula yields $E_2 = \sigma A(2T_1)^4 = \sigma A(16T_1^4)$.

(e) Factoring out the numerical constant shows that $E_2 = 16(\sigma A T_1^4) = 16E_1$. Therefore, the total radiant energy increases by a factor of 16.

Final Answer: 16

Answer: (D)

Go Back to Question 24

Q25.

Solution

Concept:

The positioning, size, and nature of an image formed by a spherical concave mirror can be determined precisely using the mirror formula along with standard Cartesian sign conventions. Linear magnification describes the ratio of image height to object height.

Solution:

(a) According to standard Cartesian sign conventions, the focal length of a concave mirror is negative ($f = -10$ cm) and the real object distance is negative ($u = -15$ cm).

(b) The mirror formula relates these quantities through the equation $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, which can be rearranged to solve for the image distance as $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$.

(c) Substituting the values gives $\frac{1}{v} = \frac{1}{-10} - \frac{1}{-15} = -\frac{1}{10} + \frac{1}{15} = \frac{-3+2}{30} = -\frac{1}{30}$, which yields an image distance of $v = -30$ cm.

(d) A negative image distance indicates that the image is formed in front of the mirror, meaning it is a real and inverted image.

(e) The linear magnification m is calculated using the formula $m = -\frac{v}{u}$. Substituting our values gives $m = -\frac{-30}{-15} = -2$, confirming a real image with magnification of -2.

Final Answer: Real, m = -2

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept:
According to the de Broglie hypothesis, moving particles exhibit wave-like properties. The wavelength associated with a matter wave depends inversely on the momentum of the particle, which can be linked directly to its kinetic energy gained through an electric potential.

Solution:

(a) When an electron of mass m and charge e is accelerated from rest through a potential difference V, it gains a kinetic energy equal to $E = eV$.

(b) The de Broglie wavelength λ associated with this moving electron is given by the formula $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2meV}}$.

(c) Substituting the fundamental constant values for Planck's constant, electron mass, and electron charge simplifies the formula for an electron to $\lambda = \frac{1.227}{\sqrt{V}}$ nm.

(d) The given potential difference is $V = 100$ V. Substituting this value into the simplified expression yields $\lambda = \frac{1.227}{\sqrt{100}}$ nm.

(e) Evaluating the square root in the denominator gives $\lambda = \frac{1.227}{10}$ nm $= 0.1227$ nm, which is approximately 0.123 nm.

Final Answer: 0.123 nm

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept:
For an object to complete a full vertical circular loop under gravity while attached to a flexible string, it must maintain a non-zero tension throughout the path. The most critical point where the string is closest to going slack is the absolute highest position of the circle.

Solution:

(a) Let v_L be the speed at the lowest point and v_H be the speed at the highest point. At the highest point, both gravity and string tension point downward toward the center.

(b) The centripetal force equation at the highest point is $T_H + Mg = \frac{Mv_H^2}{L}$. To prevent the string from going slack anywhere, the minimum tension allowed is $T_H = 0$.

(c) Setting $T_H = 0$ yields the minimum speed required at the highest position of the trajectory, which evaluates to $v_H^2 = gL$.

(d) Use the principle of conservation of mechanical energy to relate the highest point to the lowest point, noting that the vertical height change is $2L$.

(e) The energy equation states that $K_L + U_L = K_H + U_H$, which expands to $\frac{1}{2}Mv_L^2 + 0 = \frac{1}{2}Mv_H^2 + Mg(2L)$. Substituting $v_H^2 = gL$ yields $v_L = \sqrt{5gL}$.

Final Answer: $\sqrt{5gL}$

Answer: (C)

Go Back to Question 27

Q28.

Solution

Concept:

A sensitive moving-coil galvanometer can be converted into a large-scale ammeter by connecting a small resistance, called a shunt, in parallel with it. This parallel path safely bypasses the vast majority of the total circuit current around the delicate coil mechanism.

Solution:

(a) Let the galvanometer resistance be $G = 50\,\Omega$ and the current required for full-scale deflection be $I_g = 2$ mA $= 0.002$ A. The total current to be measured is $I = 2$ A.

(b) When a shunt resistor S is connected in parallel with the galvanometer, both components experience the exact same potential difference across their terminals.

(c) The current flowing through the parallel shunt branch is equal to the remaining total current, which is expressed as $I_s = I - I_g$.

(d) Equating the voltage drops across the two parallel branches gives the equilibrium equation $I_g \times G = (I - I_g) \times S$, which solves for the shunt resistance as $S = \frac{I_g G}{I - I_g}$.

(e) Substituting the values yields $S = \frac{0.002 \times 50}{2 - 0.002} = \frac{0.1}{1.998} \approx 0.05\,\Omega$.

Final Answer: $0.05\,\Omega$

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept:
Unpolarized light consists of electromagnetic waves fields oscillating randomly in all possible directions perpendicular to the path of propagation. An ideal polarizing sheet transmits only the electric field components that align parallel to its unique transmission axis.

Solution:

(a) Natural light coming from typical thermal sources is completely unpolarized, containing an equal distribution of linear polarization angles across a full circle.

(b) When this beam enters an ideal polarizing filter, the filter resolves each random field orientation into two perpendicular components: one parallel to the axis and one perpendicular.

(c) The polarizing component completely absorbs or reflects the component perpendicular to its transmission axis while letting the parallel component pass through unobstructed.

(d) Due to the uniform spatial symmetry of unpolarized light, averaging the squared cosine of all possible random angles over a complete cycle always results in a value of exactly one-half.

(e) Therefore, regardless of the orientation of the polarization transmission axis, the final transmitted intensity is always exactly equal to half of the initial unpolarized intensity, which is $\frac{I_0}{2}$.

Final Answer: $\mathrm{I}_{0\,\bar{2}}$

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept:

Radioactive decay is a random statistical process governed by first-order kinetics. The half-life is the characteristic time required for exactly one-half of the unstable nuclei in a given radioactive sample to undergo transformation into a more stable state.

Solution:

(a) Let the initial number of radioactive nuclei in the sample at time $t = 0$ be N_0. The problem states that $\frac{7}{8}$ of the initial sample has decayed.

(b) The fraction of radioactive nuclei remaining intact and undecayed in the sample is found by subtracting the decayed fraction from one, giving $N = N_0 - \frac{7}{8}N_0 = \frac{1}{8}N_0$.

(c) The standard formula for radioactive decay as a function of the number of completed half-lives n is given by the fractional relation $N = N_0\left(\frac{1}{2}\right)^n$.

(d) Equating the two expressions for the remaining nuclei yields $\frac{1}{8}N_0 = N_0\left(\frac{1}{2}\right)^n$, which simplifies directly to $\left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^n$.

(e) Comparing exponents shows that exactly $n = 3$ half-lives have elapsed. Given a single half-life of 10 days, the total time taken is $t = 3 \times 10 = 30$ days.

Final Answer: 30 days

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept:
The distribution of mass within a rigid body relative to a chosen rotational coordinate determines its moment of inertia. When shifting the rotational reference line away from the fundamental axis that passes directly through the body's center of mass, the total rotational inertia increases according to the parallel axis theorem.

Solution:

(a) For a thin uniform rod of mass m and length l, the moment of inertia about a central axis passing perpendicular to its length is given by $I_1 = \frac{1}{12}ml^2$.

(b) To find the moment of inertia about a parallel axis passing through one of its ends, we identify the shift distance between the two axes as $d = \frac{l}{2}$.

(c) Apply the parallel axis theorem, which states that the shifted moment of inertia is equal to the central moment of inertia plus the mass times the squared distance, $I_2 = I_1 + md^2$.

(d) Substituting the distance value into the equation yields $I_2 = \frac{1}{12}ml^2 + m\left(\frac{l}{2}\right)^2 = \frac{1}{12}ml^2 + \frac{1}{4}ml^2 = \frac{1+3}{12}ml^2 = \frac{1}{3}ml^2$.

(e) To find the desired structural ratio, divide the second moment of inertia by the first, which gives $\frac{I_2}{I_1} = \frac{\frac{1}{3}ml^2}{\frac{1}{12}ml^2} = \frac{12}{3} = 4$.

Final Answer: 4

Answer: (C)

Go Back to Question 31

Q32.

Solution

Concept:

When multiple electrostatic storage units are linked sequentially in a single path across a potential source, they share the exact same magnitude of electric charge regardless of their individual storage ratings. The total voltage drop is split across the elements based on their capacitive weights.

Solution:

(a) The three individual capacitors are given as $C_1 = 2\,\mu$F, $C_2 = 3\,\mu$F, and $C_3 = 6\,\mu$F, and they are connected together in a series circuit configuration.

(b) Calculate the total equivalent series capacitance C_{eq} using the reciprocal summation formula, which is written as $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$.

(c) Substituting the individual ratings gives $\frac{1}{C_{eq}} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} = \frac{3+2+1}{6} = \frac{6}{6} = 1\,\mu\text{F}^{-1}$, which means $C_{eq} = 1\,\mu$F.

(d) The total electric charge drawn from the external twelve volt battery is calculated using the definition of capacitance, $Q = C_{eq} \times V = 1\,\mu\text{F} \times 12\text{ V} = 12\,\mu\text{C}$.

(e) Because a series arrangement ensures that every connected capacitor holds an identical quantity of electrical charge, the charge residing on the middle $3\,\mu$F unit is exactly $12\,\mu$C.

Final Answer: $12\,\mu$C

Answer: (A)

Go Back to Question 32

Q33.

Solution

Concept:
When an optical beam attempts to cross a boundary from an optically dense medium into a less dense medium, it undergoes total internal reflection if the angle of incidence exceeds a specific limit. This limiting boundary condition defines the optical critical angle.

Solution:

(a) The phenomenon of total internal reflection occurs at the interface when the refracted ray travels directly along the boundary wall, corresponding to a refraction angle of ninety degrees.

(b) Snell's law describes this limiting boundary state through the simple mathematical relationship $\mu \sin(\theta_c) = 1 \times \sin(90^\circ)$, where μ is the dense material index.

(c) Simplifying the trigonometric values yields the fundamental optical relation linking the material index and the critical angle, which is expressed as $\mu = \frac{1}{\sin(\theta_c)}$.

(d) The problem states that the critical angle for this specific substance with respect to air is $\theta_c = 30^\circ$.

(e) Substituting this angle into the equation gives $\mu = \frac{1}{\sin(30^\circ)} = \frac{1}{0.5} = 2.0$. Thus, the absolute refractive index of the medium is exactly two.

Final Answer: 2.0

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:
An ideal Atwood machine consists of two unequal suspended masses connected by an inextensible light string passing over a frictionless support. The net unbalanced gravitational force acting on the combined components drives the linear acceleration of the entire physical system.

Solution:

(a) Identify the given parameters from the problem: the heavier hanging mass is $m_1 = 4$ kg, the lighter hanging mass is $m_2 = 1$ kg, and acceleration due to gravity is $g = 10$ m/s^2.

(b) Set up the individual free-body equations for each block. For the descending heavier mass, the force equation is written as $m_1 g - T = m_1 a$.

(c) For the ascending lighter mass, the tension force exceeds the downward gravitational pull, yielding the dynamic force equation $T - m_2 g = m_2 a$.

(d) Adding these two separate algebraic equations eliminates the internal string tension term, resulting in the net system relation $(m_1 - m_2)g = (m_1 + m_2)a$.

(e) Rearranging to solve for the acceleration gives $a = \frac{m_1 - m_2}{m_1 + m_2} g = \frac{4-1}{4+1} \times 10 = \frac{3}{5} \times 10 = 6$ m/s^2.

Final Answer: 6 m/s^2

Answer: (A)

Go Back to Question 34

Q35.

Solution

Concept:
A magnetic dipole placed inside an external magnetic field experiences a restoring torque that attempts to realign its magnetic orientation. The total mechanical potential energy stored within this alignment configuration depends on the spatial orientation of the dipole.

Solution:

(a) The scalar potential energy U of a magnetic dipole possessing a vector moment M inside a uniform magnetic field B is defined by the vector dot product $U = -\vec{M} \cdot \vec{B}$.

(b) Expanding this vector dot product into scalar components yields the angular relationship $U = -MB\cos\theta$, where θ represents the angle between the two vectors.

(c) To find the configuration where the stored potential energy is at an absolute minimum, we must find the angle that maximizes the value of the cosine term.

(d) The maximum possible value for the cosine function is equal to positive one, which occurs when the directional angle is exactly $\theta = 0^\circ$.

(e) Substituting this angle yields the lowest energy state, $U_{\min} = -MB$. This perfectly aligned configuration corresponds to a state of stable mechanical equilibrium.

Final Answer: 0°

Answer: (A)

Go Back to Question 35

Q36.

Solution

Concept:
The escape velocity represents the minimum initial speed required for a non-propelled ballistic body to break free from the gravitational field of a massive primary body. This threshold velocity is determined by the total mass and radial size of the planet.
Solution:

(a) The mathematical formula for the escape velocity from the surface of a spherical planet of mass M and radius R is given by $v_e = \sqrt{\frac{2GM}{R}}$.

(b) Let the parameters of the second planet be designated as $M' = 2M$ and $R' = \frac{R}{2}$. The new escape velocity from its surface is $v'_e = \sqrt{\frac{2GM'}{R'}}$.

(c) Substituting the relative mass and radius values into the new velocity equation gives the expression $v'_e = \sqrt{\frac{2G(2M)}{\frac{R}{2}}}$.

(d) Simplifying the fractional denominator shifts the numerical constant to the numerator, yielding $v'_e = \sqrt{\frac{4\times 2GM}{R}} = \sqrt{4 \times \frac{2GM}{R}}$.

(e) Factoring out the numerical square root gives $v'_e = 2 \times \sqrt{\frac{2GM}{R}} = 2v_e$. Therefore, the escape velocity doubles.

Final Answer: $2v_e$

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept:

An ideal electrical transformer modifies voltage and current levels between circuits via electromagnetic induction without incurring any energy loss. Under perfect efficiency conditions, the total electrical power entering the primary coil matches the power leaving the secondary coil.

Solution:

(a) The turns ratio for this step-up transformer configuration is given as $\frac{N_p}{N_s} = \frac{1}{10}$. The primary electrical parameters are $V_p = 220$ V and $I_p = 5$ A.

(b) The transformer voltage relationship states that the ratio of voltages is directly proportional to the turns ratio, meaning $\frac{V_s}{V_p} = \frac{N_s}{N_p} = 10$.

(c) Because the transformer operates at an ideal efficiency of one hundred percent, the conservation of power requires that $P_{\text{primary}} = P_{\text{secondary}}$, or $V_p I_p = V_s I_s$.

(d) Rearranging this power equivalence equation reveals that current is inversely proportional to the voltage ratio, which gives the current formula $I_s = I_p \times \left(\frac{V_p}{V_s}\right)$.

(e) Substituting the inverse turns ratio into the current formula yields the final value, $I_s = 5\text{ A} \times \left(\frac{1}{10}\right) = 0.5$ A.

Final Answer: 0.5 A

Answer: (B)

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Q38.

Solution

Concept:
When two independent simple harmonic oscillations occur simultaneously along the same spatial line, their combined displacement is found by applying the superposition principle. The amplitude of the resulting composite wave depends on individual amplitudes and their phase difference.
Solution:

(a) The first wave function is $y_1 = 5\sin(2\pi t)$, which gives an amplitude of $A_1 = 5$ and an initial phase angle of zero.

(b) The second wave function is $y_2 = 5\sin(2\pi t + \frac{\pi}{3})$, which gives an amplitude of $A_2 = 5$ and an initial phase angle of sixty degrees.

(c) The relative phase difference ϕ between these two harmonic oscillations is found by subtracting the phase arguments, yielding $\phi = \frac{\pi}{3} = 60°$.

(d) The mathematical expression for the resultant amplitude A obtained from vector addition is given by $A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$.

(e) Substituting the numerical values gives $A = \sqrt{5^2 + 5^2 + 2(5)(5)\cos(60°)} = \sqrt{25 + 25 + 50(0.5)} = \sqrt{50 + 25} = \sqrt{75} = 5\sqrt{3}$.

Final Answer: $5\sqrt{3}$

Answer: (C)

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Q39.

Solution

Concept:
An intrinsic semiconductor at absolute zero acts as an insulator because its valence energy band is completely full while its conduction band is entirely vacant. Thermal energy alters this state by exciting charge carriers across the forbidden bandgap.

Solution:

(a) The forbidden bandgap represents the minimum energetic jump required to liberate a bound valence electron into a mobile conduction state. For silicon, this is 1.1 eV.

(b) As the ambient temperature rises, the average thermal kinetic energy available within the crystal lattice increases proportionally.

(c) This thermal energy allows a rapidly growing number of covalent bonds to break, promoting valence electrons across the gap into the conduction band.

(d) Each promoted electron leaves behind a vacant positive state, or hole, in the valence band, thereby creating a new free electron-hole charge carrier pair.

(e) The concentration of these free mobile charge carriers increases exponentially with temperature according to a Boltzmann distribution, which causes the overall electrical conductivity to increase exponentially.

Final Answer: Increases exponentially

Answer: (A)

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Q40.

Solution

Concept:

When a body moves down a rough inclined plane at a constant velocity, it is in a state of dynamic translational equilibrium. This means the components of all forces acting parallel to the surface must balance each other out exactly, resulting in zero net acceleration.

Solution:

(a) Resolve the gravitational force acting on the mass m into two perpendicular components relative to the incline: $mg \sin\alpha$ acting down the slope, and $mg \cos\alpha$ acting perpendicular to it.

(b) The normal force N exerted by the surface opposes the perpendicular gravity component, yielding the equilibrium force equation $N = mg \cos\alpha$.

(c) Because the block slides down the plane at a constant velocity, the net driving force along the slope is zero, meaning the kinetic friction force f_k exactly balances the downward gravitational component.

(d) This gives the parallel equilibrium force relation $f_k = mg \sin\alpha$.

(e) The definition of kinetic friction relates force and normal pressure via $f_k = \mu_k N$. Substituting our expressions gives $\mu_k(mg \cos\alpha) = mg \sin\alpha$, which simplifies to $\mu_k = \frac{\sin\alpha}{\cos\alpha} = \tan\alpha$.

Final Answer: $\tan\alpha$

Answer: (C)

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Answer Key

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