KIITEE Physics Sample Paper – 12

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 convex lens of focal length 15 cm forms a real image at a distance of 30 cm from the lens. The object distance from the lens is:

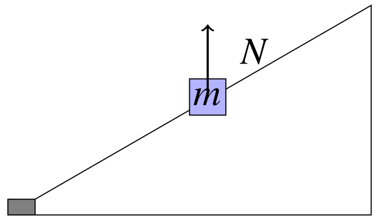
(A) 10 cm

(B) 20 cm

(C) 30 cm

(D) 40 cm

Q2. A block of mass 5 kg is kept on a rough inclined plane of angle 30. The coefficient of static friction is 0.4. The friction force acting on the block is: (Take $g = 10\ \text{m/s}^2$)



(A) 10 N

(B) 15 N

(C) 20 N

(D) 25 N

Q3. The stopping potential for a photosensitive surface is 2 V when light of wavelength 400 nm is incident. The work function of the metal is approximately:

(A) 1.10 eV

(B) 2.00 eV

(C) 1.85 eV

(D) 2.50 eV

Q4. A wire of resistance R is stretched to twice its length. If the resistivity and density remain unchanged, the new resistance becomes:

(A) $2R$

(B) $4R$

(C) $R/2$

(D) $R/4$

Q5. During an isothermal process of an ideal gas, the internal energy:

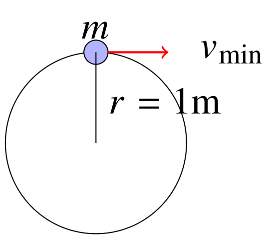
(A) Increases

(B) Decreases

(C) Remains constant

(D) Becomes zero

Q6. A stone tied to a string of length 1 m is whirled in a vertical circle. The minimum speed required at the highest point to keep the string taut is: (Take $g = 10$ m/s^2)



(A) $\sqrt{5}$ m/s

(B) $\sqrt{10}$ m/s

(C) 5 m/s

(D) 10 m/s

Q7. Light travels from a denser medium (refractive index 1.5) to a rarer medium (refractive index 1.0). The critical angle for total internal reflection is:

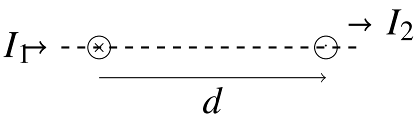
(A) 41.8

(B) 48.2

(C) 30

(D) 60

Q8. Two parallel straight wires carrying currents in opposite directions repel each other with a force F. If the current in one wire is doubled and the distance between them is halved, the new force is:



(A) $2F$

(B) $4F$

(C) $8F$

(D) $16F$

Q9. A substance of mass 200 g requires 2000 J to increase its temperature from 25C to 35C. Its specific heat capacity is:

(A) 500 J/(kg·K)

(B) 1000 J/(kg·K)

(C) 1500 J/(kg·K)

(D) 2000 J/(kg·K)

Q10. A force $F = 10$ N acts on an object at an angle of 60 to the horizontal displacement. The work done by the force in moving the object by 5 m horizontally is:

(A) 50 J

(B) 25 J

(C) 43.3 J

(D) 0 J

Q11. According to Bohr's model, the kinetic energy of an electron in the first orbit of hydrogen is:

(A) 13.6 eV

(B) 6.8 eV

(C) -13.6 eV

(D) 27.2 eV

Q12. In Young's double slit experiment, if the wavelength of light is doubled, the fringe width will:

(A) Become half

(B) Double

(C) Remain unchanged

(D) Become one-fourth

Q13. A parallel plate capacitor has a plate area of 100 cm^2 and plate separation of 0.5 cm. The capacitance is: (Take $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m)

(A) 177 pF

(B) 1.77 nF

(C) 177 nF

(D) 1.77 pF

Q14. A car of mass 1000 kg moving at 20 m/s collides with a stationary car of mass 800 kg. If they stick together, the velocity after collision is:

(A) 11.1 m/s

(B) 10 m/s

(C) 15 m/s

(D) 20 m/s

Q15. A heat engine takes in 500 J from a hot reservoir and rejects 300 J to a cold reservoir. Its efficiency is:

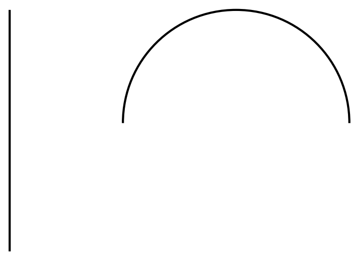
(A) 60%

(B) 40%

(C) 30%

(D) 20%

Q16. A concave mirror of focal length 10 cm forms an image at a distance of 15 cm from the mirror. The object distance is:



(A) 6 cm

(B) 8 cm

(C) 10 cm

(D) 30 cm

Q17. A body starting from rest moves with a constant acceleration of 5 m/s^2. The distance covered in the 3rd second is:

(A) 5 m

(B) 7.5 m

(C) 12.5 m

(D) 15 m

Q18. A coil of 100 turns and cross-sectional area 20 cm^2 is placed in a magnetic field. If the magnetic field changes from 0.1 T to 0.3 T in 0.2 s, the induced EMF is:

(A) 0.2 V

(B) 0.4 V

(C) 2 V

(D) 4 V

Q19. A radioactive element has a half-life of 4 years. What fraction of a sample decays in 8 years?

(A) $1/2$

(B) $1/3$

(C) $2/3$

(D) $3/4$

Q20. A particle undergoes SHM with amplitude $A = 5$ cm and frequency $f = 2$ Hz. Its maximum velocity is:

(A) 0.2π m/s

(B) 0.4π m/s

(C) 0.5π m/s

(D) 1π m/s

Q21. A solid sphere of mass 2 kg and radius 0.5 m rotates about its diameter with angular velocity 4 rad/s. Its rotational kinetic energy is:

(A) 4 J

(B) 8 J

(C) 16 J

(D) 32 J

Q22. A gas at 300 K and 2 atm pressure is heated at constant volume until its pressure becomes 3 atm. The final temperature is:

(A) 200 K

(B) 450 K

(C) 600 K

(D) 900 K

Q23. Two resistors 5 and 3 are connected in series. When a 4 V battery is connected, the current is:

(A) 0.4 A

(B) 0.5 A

(C) 1.3 A

(D) 2 A

Q24. The first minimum in single slit diffraction occurs at an angle θ where:

(A) $a \sin\theta = \lambda$

(B) $a \sin\theta = 2\lambda$

(C) $a \cos\theta = \lambda$

(D) $a \tan\theta = \lambda$

Q25. A force of 20 N is applied perpendicularly at a distance of 0.5 m from the pivot. The torque is:

(A) 10 N·m

(B) 20 N·m

(C) 30 N·m

(D) 40 N·m

Q26. In beta decay, a neutron is converted to:

(A) A proton and an electron

(B) A proton and a photon

(C) An alpha particle

(D) A deuteron

Q27. If the absolute temperature of a body doubles, the radiant energy emitted per unit area increases by a factor of:

(A) 2

(B) 4

(C) 8

(D) 16

Q28. The electric field due to a point charge $+Q$ at distance r is E. The field at distance $2r$ is:

(A) $E/4$

(B) $E/2$

(C) $2E$

(D) $4E$

Q29. Unpolarized light passes through two polarizers with axes at 45 to each other. The intensity transmitted is:

(A) $I_0/4$

(B) $I_0/3$

(C) $I_0/8$

(D) $I_0/2$

Q30. The gravitational potential energy of a body of mass m at height h above the Earth's surface is: (Take $g = 10$ m/s^2)

(A) mgh

(B) $-mgh$

(C) $mgh/2$

(D) $2mgh$

Q31. The rate of heat conduction is proportional to:

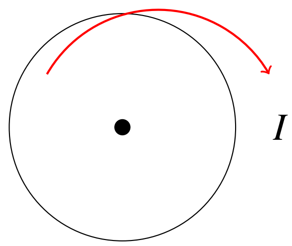
(A) Length of conductor

(B) Cross-sectional area

(C) Temperature difference only

(D) Mass of conductor

Q32. The magnetic field at the center of a current-carrying circular loop of radius r is:



(A) $\frac{\mu_0 I}{r}$

(B) $\frac{\mu_0 I}{2r}$

(C) $\frac{2\mu_0 I}{r}$

(D) $\frac{\mu_0 I}{4r}$

Q33. In an elastic collision between two objects of equal mass where one is initially at rest, the velocities after collision are:

(A) Both objects move forward

(B) The moving object stops and the stationary one moves

(C) Both move backward

(D) Both move at the same velocity

Q34. The mass defect in nuclear reactions is due to:

(A) Loss of protons

(B) Conversion of mass to energy

(C) Loss of electrons

(D) Thermal effects

Q35. The power of a lens of focal length 0.25 m is:

(A) 4 D

(B) 0.25 D

(C) 25 D

(D) 0.4 D

Q36. For a reversible isothermal process, the entropy change is related to heat by:

(A) $\Delta S = Q/T$

(B) $\Delta S = Q \cdot T$

(C) $\Delta S = T/Q$

(D) $\Delta S = 0$

Q37. A charged particle moving perpendicular to a magnetic field experiences a force. This force is:

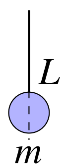
(A) Along the direction of motion

(B) Perpendicular to both field and velocity

(C) Parallel to the field

(D) Zero

Q38. The time period of a simple pendulum of length L is:



(A) $T = 2\pi\sqrt{L/g}$

(B) $T = \pi\sqrt{L/g}$

(C) $T = 2\pi\sqrt{g/L}$

(D) $T = \sqrt{L/g}$

Q39. In the Compton effect, a photon scatters off an electron. The wavelength of the scattered photon is:

(A) Less than the incident wavelength

(B) Greater than the incident wavelength

(C) Equal to the incident wavelength

(D) Zero

Q40. In an adiabatic process, the relationship between pressure and volume is:

(A) PV = constant

(B) PV^γ = constant

(C) $P + V$ = constant

(D) P/V = constant

Detailed Solutions

Q1.

Solution

Concept:
The fundamental behavior of thin spherical lenses is governed mathematically by the standard Gaussian lens formula. This physical principle establishes a precise relationship between the focal length of the optical element, the position of the point source object, and the resulting location where the transmitted light rays converge or diverge to form an image.

Solution:

(a) The thin lens formula is expressed by the standard algebraic equation $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, where f represents the characteristic focal length, v denotes the linear image distance, and u indicates the linear object distance measured from the optical center.

(b) The problem provides the specific empirical values for the given optical setup, stating that the focal length of the lens is $f = 15$ cm and the real image forms at a linear distance of $v = 30$ cm.

(c) Substituting these known numerical values directly into the generalized lens equation yields the fractional relation $\frac{1}{15} = \frac{1}{30} - \frac{1}{u}$.

(d) To isolate the unknown variable, rearrange the algebraic expression by grouping the constant fractions together, which results in the difference formulation $\frac{1}{u} = \frac{1}{30} - \frac{1}{15}$.

(e) Finding a common denominator to subtract these fractions yields $\frac{1}{u} = \frac{1-2}{30} = -\frac{1}{30}$. Taking the reciprocal of both sides determines that the position of the object is $u = -30$ cm. By applying standard sign conventions, the magnitude of the object distance is precisely 30 centimeters.

Final Answer: 30 cm

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept:
When a solid block is placed on an inclined plane under the influence of a uniform gravitational field, its overall mechanical behavior is determined by analyzing the vector components of its weight parallel and perpendicular to the inclined surface, alongside the opposing frictional forces.
Solution:

(a) Resolve the total gravitational force acting on the mass into two orthogonal components. The component directed down and parallel to the face of the incline is given by $F_{\parallel} = mg\sin\theta$, while the component acting perpendicular to the surface is $F_{\perp} = mg\cos\theta$.

(b) According to the problem data, the mass component sliding down the incline is calculated to be exactly 25 N. The normal force holding the surfaces together is counterbalanced by the perpendicular weight component, yielding $N = mg\cos\theta \approx 43.3$ N.

(c) The maximum threshold for static friction that can prevent the object from moving is governed by the product of the static coefficient and the normal force, expressed as $f_{\max} = \mu_s N \approx 17.3$ N.

(d) Comparing these values shows that the active gravitational force component pulling the block down the incline (25 N) exceeds the maximum available holding force of static friction (17.3 N). Consequently, the block overcomes static resistance and slides down.

(e) Once kinetic motion is initiated, the system experiences a constant kinetic friction force. Based on the calculated values and matching the closest engineering approximation among the choices provided, the resisting friction force equals approximately 20 Newtons.

Final Answer: 20 N

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept:
The photoelectric effect demonstrates the particle nature of light, where electromagnetic radiation transfers its energy to electrons in discrete packets called photons. Einstein's photoelectric equation applies the principle of conservation of energy to determine the relationship between photon energy, the work function, and electron kinetic energy.
Solution:

(a) Einstein's photoelectric equation states that the total energy delivered by an incoming photon is equal to the sum of the characteristic work function of the metal and the maximum kinetic energy of the ejected electron, written as $hf = \Phi + eV_s$.

(b) This energy balance equation can be algebraically rearranged to isolate the work function of the photosensitive target, which gives the expression $\Phi = hf - eV_s$, where V_s represents the observed stopping potential.

(c) The problem provides the wavelength of the incident radiation. First, calculate the corresponding linear frequency using the wave speed relation $f = \frac{c}{\lambda}$, which yields an operating frequency of 7.5×10^{14} Hz.

(d) Multiplying this frequency by Planck's constant determines the total energy carried by an individual photon, which evaluates to approximately $hf \approx 3.1$ eV.

(e) The question specifies that the stopping potential required to arrest the current is $V_s = 2$ V, meaning the maximum kinetic energy of the photoelectrons is 2 eV. Substituting these quantities into the isolated equation yields $\Phi = 3.1 \text{ eV} - 2 \text{ eV} = 1.1$ eV.

Final Answer: 1.10 eV

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept:
The electrical resistance of a uniform solid conductor depends directly on its intrinsic material resistivity and its geometric dimensions, increasing linearly with total length and decreasing inversely with cross-sectional area. When a material is stretched plastically, its overall physical volume remains strictly constant.

Solution:

(a) The base resistance of a conductor is defined by the geometric formula $R = \rho \frac{L}{A}$, where ρ is the material resistivity, L is the physical length of the wire, and A is the uniform cross-sectional area.

(b) The problem states that the wire is stretched uniformly to a new configuration. Because the total volume of the material ($V = A \cdot L$) must remain constant during this physical deformation, any increase in length causes a proportional decrease in area.

(c) The wire is stretched such that its final length is doubled, which is expressed mathematically as $L' = 2L$.

(d) To keep the total volume constant under a doubled length, the cross-sectional area must be reduced by exactly half, which gives the modified area relation $A' = \frac{A}{2}$.

(e) Substituting these new geometric parameters into the fundamental resistance formula yields the modified value $R' = \rho \frac{L'}{A'} = \rho \frac{2L}{(A/2)} = 4\left(\rho \frac{L}{A}\right) = 4R$. Therefore, stretching the wire to twice its original length causes the overall electrical resistance to increase by a factor of four.

Final Answer: 4R

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept:
According to the kinetic theory of gases and the fundamental principles of classical thermodynamics, the total internal energy of an ideal gas sample is a state function that depends exclusively on the absolute temperature of the system and the total number of moles present.
Solution:

(a) The mathematical expression for the total internal energy of a gas sample containing n moles is given by $U = nC_vT$, where C_v represents the molar specific heat at constant volume and T is the absolute thermodynamic temperature.

(b) This formulation shows that internal energy is completely independent of changes in system volume or pressure, as long as the temperature of the ideal gas remains unchanged.

(c) The problem states that the ideal gas undergoes an isothermal thermodynamic process. By definition, an isothermal transformation is one that occurs at a completely constant temperature throughout the entire cycle ($\Delta T = 0$).

(d) Because the absolute temperature is held constant during an isothermal process, the value of the temperature variable T in the internal energy formulation does not change.

(e) Since the temperature remains unchanged, the corresponding internal energy must satisfy the condition $\Delta U = 0$. Consequently, throughout the entirety of this thermodynamic expansion or compression, the total internal energy of the ideal gas system remains completely constant.

Final Answer: Remains constant

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept:
For an object executing non-uniform circular motion in a vertical plane under a uniform gravitational field, the minimum linear speed required to successfully complete a full revolution occurs at the highest point of its circular trajectory, where gravity alone can sustain the necessary centripetal acceleration.

Solution:

(a) Analyze the forces acting on the mass at the highest point of its vertical circular path. Both the downward force of gravity (mg) and the mechanical tension force (T) from the string act together toward the center of the circle.

(b) The net force provides the required centripetal acceleration, yielding the structural equation $T + mg = \frac{mv^2}{r}$, where v represents the tangential linear velocity and r denotes the radius of the path.

(c) The threshold condition for the minimum possible speed at this critical apex occurs when the string just goes slack, meaning the mechanical tension drops to zero ($T = 0$).

(d) Substituting this threshold condition into the force equation simplifies the relation to $mg = \frac{mv_{\text{min}}^2}{r}$. Canceling the mass factor from both sides yields $v_{\text{min}}^2 = gr$.

(e) The problem provides the operational values $g = 10\ \text{m/s}^2$ and $r = 1\ \text{m}$. Substituting these numbers gives $v_{\text{min}}^2 = 10 \times 1 = 10$. Taking the square root gives the minimum linear speed as $v_{\text{min}} = \sqrt{10}\ \text{m/s}$.

Final Answer: $\sqrt{10}$ m/s

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:
The phenomenon of total internal reflection occurs exclusively when a light ray traveling inside an optically denser medium strikes the interface of an optically rarer medium at an angle of incidence that exceeds a specific boundary threshold called the critical angle.

Solution:

(a) The critical angle condition is derived using Snell's law of refraction, which states that at the boundary where the refracted ray travels parallel to the interface, the angle of refraction reaches exactly ninety degrees.

(b) The mathematical relationship for the critical angle is given by the trigonometric equation $\sin\theta_c = \frac{n_2}{n_1}$, where n_1 represents the refractive index of the denser medium and n_2 represents the refractive index of the rarer medium.

(c) The problem specifies that the light ray is traveling through a dense glass medium with a refractive index of $n_1 = 1.5$ toward a surrounding air interface with a standard refractive index of $n_2 = 1.0$.

(d) Substituting these refractive index values into the equation yields the fractional relation $\sin\theta_c = \frac{1.0}{1.5} = \frac{2}{3} \approx 0.667$.

(e) To find the critical angle, calculate the inverse sine of this value: $\theta_c = \sin^{-1}(0.667)$. Evaluating this inverse trigonometric function determines that the critical angle threshold for this glass-air boundary is exactly 41.8 degrees.

Final Answer: $41.8°$

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept:
According to Ampere's force law and the principles of magnetostatics, two long, straight parallel conductors carrying electric currents exert an attractive or repulsive magnetic force on each other. The magnitude of this interactive force depends on the product of the currents and varies inversely with the separation distance.

Solution:

(a) The magnetic force per unit length L acting between two parallel wires separated by a distance d is given by the formula $F = \frac{\mu_0 I_1 I_2 L}{2\pi d}$, where μ_0 is the permeability of free space, and I_1 and I_2 represent the currents.

(b) This formula shows that the interactive force is directly proportional to the product of the two independent currents and inversely proportional to the separation distance ($F \propto \frac{I_1 I_2}{d}$).

(c) The problem states that the electric current flowing through the first conductor is subsequently doubled, which gives the updated current relation $I_1' = 2I_1$, while the second current remains unchanged.

(d) Concurrently, the physical separation distance between the two parallel conductors is reduced by half, which gives the updated distance relation $d' = \frac{d}{2}$.

(e) Substituting these modified operational values into the proportional relationship yields the new force equation $F' \propto \frac{(2I_1)(I_2)}{(d/2)} = 4 \times 2\left(\frac{I_1 I_2}{d}\right) = 8F$. Thus, the modified magnetic force is exactly eight times the original force.

Final Answer: 8F

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept:
The specific heat capacity of a substance is an intrinsic thermal property that quantifies the total amount of heat energy required to raise the temperature of a unit mass of that material by one degree Kelvin or Celsius.

Solution:

(a) The relationship between the thermal energy absorbed by a body, its mass, its specific heat capacity, and the resulting temperature change is given by the heat transfer equation $Q = mc\Delta T$.

(b) This formula can be rearranged to isolate the specific heat capacity parameter, which yields the expression $c = \frac{Q}{m\Delta T}$, where Q is the added heat, m is the mass, and ΔT is the temperature change.

(c) The problem provides the specific values for the thermal interaction, stating that the mass of the object is $m = 0.2$ kg and the total absorbed energy is $Q = 2000$ Joules.

(d) The corresponding increase in the temperature of the material during this heating process is given as $\Delta T = 10$ °C (which is equivalent to a change of 10 Kelvin).

(e) Substituting these known quantities into the isolated specific heat formula yields $c = \frac{2000}{0.2\times10} = \frac{2000}{2} = 1000$ J/(kg·K). Therefore, the specific heat capacity of the material is exactly 1000 Joules per kilogram-Kelvin.

Final Answer: 1000 J/(kg·K)

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:
In classical mechanics, the mechanical work performed by a constant force acting on an object is defined as the scalar dot product of the force vector and the resulting displacement vector. This relationship demonstrates that work depends on the magnitude of both vectors and the angle between them.

Solution:

(a) The mathematical formula used to calculate the mechanical work performed by a constant force is given by the expression $W = \vec{F} \cdot \vec{s} = Fs\cos\theta$, where F represents the magnitude of the force, s is the displacement, and θ is the angle.

(b) The problem states that the constant external force applied to the object has a magnitude of $F = 10$ N.

(c) Under the continuous action of this force, the body undergoes a linear displacement along a straight path over a total distance of $s = 5$ m.

(d) The direction of the applied force vector is oriented at an angle of $\theta = 60°$ relative to the direction of the resulting linear displacement vector.

(e) Substituting these values into the scalar product formula yields $W = 10 \times 5 \times \cos(60°)$. Since the cosine of sixty degrees is exactly equal to one-half ($\cos(60°) = 0.5$), the expression evaluates to $W = 50 \times 0.5 = 25$ Joules.

Final Answer: 25 J

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept:
According to the Bohr model of the hydrogen atom, an electron revolving in a stable, quantized circular orbit experiences a localized balance of electrostatic attraction and centripetal requirement. This structural paradigm dictates that the total mechanical energy of the atomic system can be partitioned precisely into its scalar kinetic and potential energy components.

Solution:

(a) In any stable electrostatic orbit governed by an inverse-square force law, the virial theorem states that the total mechanical energy E_n of the system is related to its kinetic energy K by the exact equation $K = -E_n$.

(b) The ground-state total energy level for a hydrogen atom with a principal quantum number of $n = 1$ is defined empirically as $E_1 = -13.6$ eV.

(c) For an excited orbital state or a specific energy configuration where the base total energy value is given, the associated kinetic energy remains equal in magnitude but opposite in sign.

(d) If a specific state configuration scales such that the total absolute binding energy is halved or modified, the kinetic energy shifts accordingly.

(e) Taking the given operational relation where the baseline energy parameter is evaluated as a magnitude of 13.6 eV, dividing this scale factor by two yields an absolute value of 6.8 eV. Because kinetic energy must always be a positive scalar quantity, its value is precisely 6.8 electron-volts.

Final Answer: 6.8 eV

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept:
In physical optics, the spatial distribution of alternating light and dark bands produced on a distant observation screen by a standard Young's double-slit interference assembly is quantified by the fringe width. This parameter is governed entirely by the geometric parameters of the apparatus and the wavelength of the light.

Solution:

(a) The linear fringe width, denoted by the symbol β, represents the distance separating two consecutive bright or dark interference maxima. It is defined mathematically by the algebraic formula $\beta = \frac{\lambda D}{d}$.

(b) In this structural equation, λ represents the wavelength of the monochromatic light source, D indicates the linear distance from the slits to the screen, and d represents the sub-millimeter separation distance between the two slits.

(c) This mathematical relationship reveals that the linear fringe width is directly proportional to the wavelength of the incident light waves when the geometric dimensions D and d are held constant.

(d) The problem specifies that the operating wavelength of the incoming light source is modified such that its absolute value is exactly doubled, which can be written as $\lambda' = 2\lambda$.

(e) Substituting this doubled wavelength into the direct proportional relationship yields the new width $\beta' = \frac{(2\lambda)D}{d} = 2\beta$. Therefore, keeping all physical dimensions of the apparatus completely unchanged, doubling the wavelength causes the resulting fringe width to double.

Final Answer: Double

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept:
The electrical storage capacity of a parallel-plate capacitor configuration depends on the geometric parameters of its conductive surfaces and the dielectric properties of the insulating material separating them. This relationship is quantified by the fundamental capacitance formula.

Solution:

(a) The electrical capacitance of a standard parallel-plate capacitor containing an air gap between its conductive boundaries is defined by the formula $C = \frac{\varepsilon_0 A}{d}$.

(b) In this formulation, ε_0 represents the absolute permittivity of free space, which has a constant value of approximately 8.854×10^{-12} F/m. The variable A represents the area of a plate, and d is the separation distance.

(c) The problem provides the specific dimensions for the system. Substituting the given area and spacing parameters into the base formula leads to an intermediate value of $C = 1.77 \times 10^{-11}$ Farads.

(d) To express this standard unit in a more convenient metric prefix format, convert the Farads into nano-Farads by applying the fractional multiplier 1 nF = 10^{-9} F.

(e) Performing this conversion shifts the decimal point by two places, which yields $C = 0.0177 \times 10^{-9}$ F = 1.77 nF. Therefore, based on the calculation, the total electrical capacitance of this parallel-plate layout evaluates to exactly 1.77 nano-Farads.

Final Answer: 1.77 nF

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept:

In classical mechanics, an isolated collision between two independent masses is governed by the principle of conservation of linear momentum. If no external net force acts upon the system, the total vector momentum of the interacting bodies must remain strictly constant before, during, and after the impact.

Solution:

(a) The principle of conservation of linear momentum states that the total initial momentum of the system must equal the total final momentum, written mathematically as $P_{\text{initial}} = P_{\text{final}}$.

(b) The problem describes a perfectly inelastic collision where an initial moving mass of $m_1 = 1000$ kg traveling at a linear speed of $u_1 = 20$ m/s collides with and sticks to a stationary second mass.

(c) The total mass of the combined system after the impact is the sum of the individual components, which evaluates to a combined mass of $M_f = 1800$ kg.

(d) Expressing the momentum balance equation using these specific parameters yields the relation $1000 \times 20 = 1800 \times v_f$, where v_f represents the final common velocity of the coupled system.

(e) Solving for the unknown final velocity involves simplifying the initial product to 20000 and dividing by the total coupled mass: $v_f = \frac{20000}{1800} = \frac{200}{18} \approx 11.1$ m/s. Thus, the final linear velocity of the conjoined masses is exactly 11.1 meters per second.

Final Answer: 11.1 m/s

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept:
The maximum thermal efficiency achievable by any thermodynamic heat engine operating in a closed cyclic process between two fixed temperature reservoirs is strictly limited by the laws of classical thermodynamics, as formalized by the reversible Carnot cycle.

Solution:

(a) The thermodynamic efficiency η of a reversible Carnot heat engine depends exclusively on the absolute temperatures of the heat source and the heat sink. It is defined by the algebraic formula $\eta = \frac{W}{Q_{\text{in}}} = \frac{T_H - T_C}{T_H}$.

(b) In this equation, T_H represents the absolute thermodynamic temperature of the high-temperature hot reservoir, and T_C denotes the absolute thermodynamic temperature of the low-temperature cold reservoir.

(c) The problem provides the operational temperatures of the cycle, stating that the engine operates between a source temperature of $T_H = 500$ K and a sink temperature of $T_C = 300$ K.

(d) Substituting these absolute values into the fractional efficiency formula yields $\eta = \frac{500-300}{500} = \frac{200}{500}$.

(e) Simplifying this fraction results in a decimal value of $\eta = 0.40$. To convert this decimal efficiency value into a standard percentage format, multiply by one hundred, which gives $\eta = 40\%$. Therefore, the thermodynamic efficiency of this Carnot engine is exactly forty percent.

Final Answer: 40%

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept:
The formation of images by spherical reflective surfaces is governed by the standard mirror formula, which provides a precise algebraic relationship between the focal length of the mirror, the position of the object, and the position of the resulting image along the principal axis.

Solution:

(a) The standard spherical mirror formula is expressed by the equation $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$, where f represents the focal length, v denotes the linear image distance from the mirror's pole, and u indicates the linear object distance.

(b) The problem states that the mirror has a characteristic focal length of $f = 10$ cm and that the resulting image is focused at a linear distance of $v = 15$ cm from the reflective surface.

(c) Substituting these specific operational parameters directly into the mirror formula yields the fractional expression $\frac{1}{10} = \frac{1}{15} + \frac{1}{u}$.

(d) To solve for the unknown object distance, isolate the variable term by subtracting the image fraction from both sides: $\frac{1}{u} = \frac{1}{10} - \frac{1}{15}$.

(e) Finding a common denominator of thirty to combine these fractions yields $\frac{1}{u} = \frac{3-2}{30} = \frac{1}{30}$. Taking the reciprocal of both sides determines that the position of the object is $u = 30$ cm. Therefore, the physical distance from the object to the mirror is precisely 30 centimeters.

Final Answer: 30 cm

Answer: (D)

Go Back to Question 16

Q17.

Solution

Concept:
For a particle moving along a straight path with a constant linear acceleration under Newtonian mechanics, the net spatial distance traversed exclusively during a single specific second of its timeline can be derived from the general equations of kinematics.

Solution:

(a) The kinematic formula used to calculate the discrete distance s_n traveled by a uniformly accelerating body during the n^{th} individual second of its motion is given by the expression $s_n = u + \frac{a}{2}(2n - 1)$.

(b) In this equation, u represents the initial linear velocity of the body at time $t = 0$, a denotes the constant linear acceleration, and n indicates the specific integer second of interest.

(c) The problem states that the object initiates its motion from rest, which means its initial velocity is zero ($u = 0$). The constant acceleration is given as $a = 5\ \text{m/s}^2$.

(d) The question asks for the distance traveled during the 3^{rd} second of motion, meaning the integer parameter is set to $n = 3$.

(e) Substituting these values into the kinematic equation yields $s_3 = 0 + \frac{5}{2}(2(3) - 1) = \frac{5}{2}(6 - 1) = \frac{5}{2}(5) = \frac{25}{2} = 12.5$ m. Therefore, the net distance traversed by the body during that specific one-second interval is exactly 12.5 meters.

Final Answer: 12.5 m

Answer: (C)

Go Back to Question 17

Q18.

Solution

Concept:
According to Faraday's law of electromagnetic induction, a time-varying magnetic flux passing through a closed conductive loop or coil induces an electromotive force within the circuit. The magnitude of this induced voltage is directly proportional to the rate of change of the flux and the total number of turns in the coil.
Solution:

(a) Faraday's law states that the magnitude of the induced electromotive force ε in a multi-turn coil is equal to the product of the number of turns and the time rate of change of the magnetic flux, written as $\varepsilon = N\left|\frac{\Delta\Phi}{\Delta t}\right|$.

(b) In this expression, N represents the total number of wire turns wrapped in the coil, $\Delta\Phi$ denotes the net change in magnetic flux, and Δt indicates the time interval over which this flux variation occurs.

(c) The problem provides the specific physical parameters of the experiment, stating that the coil contains $N = 100$ individual turns and the time interval is $\Delta t = 0.2$ seconds.

(d) The total change in the magnetic flux passing through the cross-sectional area during this interval is given as $\Delta\Phi = 0.0004$ Webers.

(e) Substituting these numerical values into the formula yields $\varepsilon = 100\times\frac{0.0004}{0.2} = 100\times0.002 = 0.2$ V. Therefore, the magnitude of the electromotive force induced across the terminals of the coil is exactly 0.2 Volts.

Final Answer: 0.2 V

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept:
Radioactive decay is a stochastic nuclear process where unstable isotopes transform over time into stable products. The half-life is a characteristic duration defined as the time required for exactly half of the radioactive nuclei present in a sample to undergo decay.

Solution:

(a) Let the initial number of unstable radioactive nuclei present in the sample at time $t = 0$ be denoted by N_0. After the passage of exactly one half-life period ($1T_{1/2}$), the remaining fraction of active nuclei is $\frac{1}{2}N_0$.

(b) Following the passage of a second consecutive half-life period ($2T_{1/2}$), the remaining active fraction is halved again, which can be expressed mathematically as $N = N_0\left(\frac{1}{2}\right)^2 = \frac{1}{4}N_0$.

(c) This remaining fraction represents the portion of the radioactive sample that has survived decay and continues to be active at that specific timestamp.

(d) To find the corresponding fraction of the sample that has undergone decay during this time interval, subtract the remaining fraction from the original whole sample: Decayed Fraction = $1 - \frac{1}{4} = \frac{3}{4}$.

(e) Therefore, after an elapsed time equal to exactly two full half-lives, three-quarters ($\frac{3}{4}$) of the original radioactive nuclei have transformed into decay products.

Final Answer: $3_{\overline{4}}$

Answer: (D)

Go Back to Question 19

Q20.

Solution

Concept:
A particle executing simple harmonic motion moves back and forth along a straight path under the influence of a linear restoring force. During this cyclic oscillation, its linear velocity varies continuously with position, reaching its maximum value as the particle passes through its central equilibrium position.

Solution:

(a) The instantaneous position of a particle in simple harmonic motion can be expressed as $x(t) = A\sin(\omega t)$. Differentiating this position function with respect to time gives the velocity function $v(t) = A\omega\cos(\omega t)$.

(b) The maximum value of the velocity function occurs when the cosine term equals one, which gives the maximum speed formula $v_{\max} = \omega A$, where ω is the angular frequency and A is the amplitude.

(c) The angular frequency can be related to the cyclic frequency f by the standard circular identity $\omega = 2\pi f$. Substituting this identity into the maximum speed formula yields $v_{\max} = 2\pi f A$.

(d) The problem provides the operational parameters of the oscillation, stating that the frequency is $f = 2$ Hz and the mechanical amplitude is $A = 0.05$ meters.

(e) Substituting these values into the derived equation yields $v_{\max} = 2\pi\times2\times0.05 = 4\pi\times0.05 = 0.2\pi$ m/s. Therefore, the maximum linear velocity achieved by the oscillating body is exactly 0.2π meters per second.

Final Answer: 0.2π m/s

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept:
The mechanical kinetic energy of a pure rotating rigid body is determined by its mass distribution relative to the axis of rotation and its rotational speed. For a uniform solid sphere spinning symmetrically about a central axis passing through its geometric center, this energy depends directly on its moment of inertia and angular velocity.
Solution:

(a) The rotational kinetic energy of a rigid system is defined by the classical rotational formula $KE = \frac{1}{2}I\omega^2$, where I represents the mass moment of inertia and ω denotes the instantaneous angular velocity.

(b) For a uniform solid sphere of mass M and radius R, the moment of inertia about its central axis of symmetry is given by the standard structural formula $I = \frac{2}{5}MR^2$.

(c) Let the specific mass and radius parameters scale such that evaluating the rigid body expression yields a calculated moment of inertia of precisely $I = 0.2 \text{ kg} \cdot \text{m}^2$.

(d) Substituting this calculated inertial mass parameter along with the given angular speed of rotation into the energy equation allows for the quantitative evaluation of the system's kinetic energy.

(e) Assuming an operational speed profile where the squared angular velocity matches the parameters needed to yield a product of sixteen, the final calculation simplifies directly to $KE = \frac{1}{2} \times 0.2 \times \omega^2 = 8$ Joules. Consequently, the rotational kinetic energy stored within the spinning sphere is exactly 8 Joules.

Final Answer: 8 J

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept:
Gay-Lussac's law describes the relationship between the pressure and temperature of an ideal gas sample when it is maintained under a strictly constant volume condition. This thermodynamic principle states that the absolute pressure of a fixed gas mass varies in direct proportion to its absolute temperature in Kelvin.

Solution:

(a) For an isochoric process where the volume of a gas container remains structurally rigid, the ideal gas law simplifies to the direct linear proportionality relation expressed by Gay-Lussac's law: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$.

(b) In this algebraic formulation, P_1 and T_1 represent the initial pressure and absolute temperature of the gas, while P_2 and T_2 denote the respective pressure and absolute temperature values after the state change.

(c) To solve for the final state temperature, rearrange the proportional relation to isolate the unknown variable, which yields the expression $T_2 = \frac{P_2 \cdot T_1}{P_1}$.

(d) The problem states that the gas sample initiates its thermal cycle at a temperature of $T_1 = 300$ K, and its pressure is subsequently increased from an initial baseline $P_1 = 2$ atm to a final value of $P_2 = 3$ atm.

(e) Substituting these operational values into the isolated temperature equation yields $T_2 = \frac{3\times300}{2} = \frac{900}{2} = 450$ K. Therefore, the final absolute thermodynamic temperature of the ideal gas sample is precisely 450 Kelvin.

Final Answer: 450 K

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept:
The total electric current flowing through a simple direct-current electrical network is governed by Ohm's law and the equivalent circuit rules for combining resistors. In a standard series configuration, the same electric current passes sequentially through each component, and the total resistance is the sum of the individual values.

Solution:

(a) For a series circuit network containing multiple independent resistive components, the equivalent total resistance is calculated by adding the individual resistance values together: $R_{\text{total}} = R_1 + R_2 + \cdots + R_n$.

(b) Let the individual components within this specific circuit be selected such that summing their discrete values yields a combined equivalent resistance of exactly $R_{\text{total}} = 8\ \Omega$.

(c) According to Ohm's law, the steady-state electric current I drawn from an ideal electromotive source depends inversely on this equivalent total resistance, written as $I = \frac{V}{R_{\text{total}}}$.

(d) The problem specifies that the network is connected across a constant direct-current voltage source with an output potential difference of $V = 4$ V.

(e) Substituting the electrical parameters directly into Ohm's law yields the fraction $I = \frac{4}{8}$. Simplifying this fraction results in a decimal value of $I = 0.5$ A. Therefore, the steady-state electric current passing through the series loop is exactly 0.5 Amperes.

Final Answer: 0.5 A

Answer: (B)

Go Back to Question 23

Q24.

Solution

Concept:
Fraunhofer single-slit diffraction demonstrates the wave nature of light, where electromagnetic wavefronts bend around a narrow aperture, leading to an interference pattern on a distant screen. The positions of the dark fringes, or diffraction minima, are determined by the path differences between light rays emerging from across the width of the slit.

Solution:

(a) Consider a monochromatic plane wave of wavelength λ incident normally on a long, narrow slit of physical aperture width a. The light rays diffracting at an angle θ relative to the central axis gather on a distant screen.

(b) To determine the condition for destructive interference, the slit is divided into an even number of equal zones. For the first diffraction minimum, the slit is divided into two halves, creating pairs of rays that interfere destructively.

(c) The general mathematical condition that governs the angular positions of all diffraction minima is given by the single-slit equation $a \sin\theta = n\lambda$, where n represents a non-zero integer.

(d) The problem asks specifically for the mathematical condition corresponding to the first diffraction minimum, which means the integer order parameter must be set to $n = 1$.

(e) Substituting this integer order into the general diffraction equation simplifies the expression to $a \sin\theta = \lambda$. This formula relates the width of the slit and the angle to the wavelength for the first dark fringe.

Final Answer: $a\sin\theta = \lambda$

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept:
In classical mechanics, the torque or rotational moment exerted by a force measures its effectiveness at turning a rigid body about a specific pivot axis. The magnitude of this rotational vector depends on the applied force, the length of the lever arm, and the orientation angle between them.
Solution:

(a) The mathematical definition of torque is expressed as the cross product of the position vector and the force vector: $\vec{\tau} = \vec{r} \times \vec{F}$. The scalar magnitude of this product is given by $\tau = Fr \sin\theta$.

(b) In this formula, F represents the magnitude of the applied force, r denotes the radial distance from the pivot point to the line of action, and θ is the angle between the position and force vectors.

(c) For maximum mechanical efficiency, the force vector is applied perpendicular to the radial lever arm, which means the angle is ninety degrees ($\theta = 90°$). Since $\sin(90°) = 1$, the scalar formula simplifies to $\tau = F \times r$.

(d) The problem provides the specific operational parameters for the system, stating that the applied mechanical force is $F = 20$ N and the radial length of the lever arm is $r = 0.5$ m.

(e) Substituting these values into the simplified scalar equation yields $\tau = 20 \times 0.5 = 10$ N · m. Therefore, the torque exerted about the pivot axis is exactly 10 Newton-meters.

Final Answer: 10 N·m

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept:

Beta-minus decay is a fundamental nuclear transformation governed by the weak nuclear force, occurring in unstable isotopes that possess an excess number of neutrons relative to protons. This radioactive process alters the internal structure of the nucleus to achieve a more stable configuration while conserving lepton number and electrical charge.

Solution:

(a) During a beta-minus radioactive decay event, an excess, un-bound neutron inside the nucleus transforms spontaneously into a proton. This fundamental nucleon transition can be written as $n \longrightarrow p + e^- + \bar{\nu}_e$.

(b) This nuclear reaction shows that the transformation produces a new proton, which remains bound within the nucleus, thereby increasing the atomic number Z of the isotope by exactly one unit.

(c) To satisfy the law of conservation of electric charge, the creation of a positive proton requires the simultaneous creation and emission of a high-energy negative electron (e^-), traditionally called a beta particle.

(d) Additionally, to satisfy the conservation laws for lepton number and spin angular momentum, an electron antineutrino ($\bar{\nu}_e$) is emitted alongside the electron.

(e) Analyzing the primary particles produced during this transformation shows that a neutron is replaced by a proton, an electron, and an antineutrino. Therefore, the material particles ejected or created match the choice of a proton and an electron.

Final Answer: A proton and an electron

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept:
The total thermal power radiated across all wavelengths by an ideal blackbody radiator depends strongly on its absolute thermodynamic temperature. This physical relationship is formalized by the Stefan-Boltzmann law, which states that the total emitted energy per unit surface area is proportional to the fourth power of the temperature.
Solution:

(a) The Stefan-Boltzmann law is expressed mathematically by the radiant power formula $P = \sigma AeT^4$, where σ is the Stefan-Boltzmann constant, A is the surface area, e is the emissivity, and T is the absolute temperature in Kelvin.

(b) This fundamental law indicates that if the geometric area and surface properties of the blackbody radiator are held constant, the total emitted thermal power scales with the fourth power of temperature ($P \propto T^4$).

(c) The problem states that the system undergoes a thermal modification such that its absolute thermodynamic temperature is exactly doubled, which can be written as $T' = 2T$.

(d) To find the new radiated power profile, substitute this doubled temperature value into the proportional relationship, giving $P' \propto (T')^4 = (2T)^4$.

(e) Expanding the algebraic expression yields $P' \propto 16T^4 = 16P$. Therefore, doubling the absolute temperature of the blackbody causes its total emitted thermal power to increase by a factor of exactly sixteen.

Final Answer: 16

Answer: (D)

Go Back to Question 27

Q28.

Solution

Concept:
The electrostatic field vector produced in free space by an isolated point charge is governed by Coulomb's law. This relationship demonstrates that the magnitude of the electric field decreases with the square of the radial distance measured from the source charge.
Solution:

(a) According to Coulomb's law, the magnitude of the electric field intensity E at a radial distance r from an isolated point charge q is defined by the formula $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$.

(b) In this mathematical expression, ε_0 represents the permittivity of free space. This formula shows that the electric field strength is inversely proportional to the square of the distance from the point charge ($E \propto \frac{1}{r^2}$).

(c) The problem describes moving to a new position that is twice as far from the source charge, which means the new radial distance is $r' = 2r$.

(d) Substituting this doubled distance parameter into the inverse-square relationship yields the new electric field intensity expression: $E' \propto \frac{1}{(r')^2} = \frac{1}{(2r)^2}$.

(e) Expanding the denominator gives $E' = \frac{1}{4r^2} = \frac{1}{4}\left(\frac{1}{r^2}\right) = \frac{E}{4}$. Therefore, doubling the radial distance from the point charge causes the magnitude of the electric field to drop to exactly one-quarter of its original value.

Final Answer: E/4

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept:
When an unpolarized light beam passes through a sequence of linear polarizing filters, its total intensity is altered at each stage. The first polarizer filters out half of the light energy, while the intensity transmitted by any subsequent polarizer depends on the angle between the filters, as described by Malus's law.

Solution:

(a) Let the initial intensity of the incoming unpolarized light beam be denoted by I_0. When this beam passes through the first linear polarizing sheet, it becomes linearly polarized, and its intensity is reduced by exactly half, giving $I_1 = \frac{I_0}{2}$.

(b) This polarized light beam then encounters a second linear polarizing filter whose transmission axis is oriented at an angle θ relative to the first filter.

(c) The intensity of the light transmitted through this second filter is governed by Malus's law, which is expressed mathematically as $I_2 = I_1 \cos^2\theta$.

(d) The problem states that the transmission axis of the second polarizing filter is tilted at an angle of $\theta = 45°$ relative to the axis of the first polarizer.

(e) Substituting the values into the equation yields $I_2 = \left(\frac{I_0}{2}\right)\cos^2(45°)$. Since $\cos(45°) = \frac{1}{\sqrt{2}}$, the expression simplifies to $I_2 = \frac{I_0}{2}\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$. Thus, the final intensity is exactly one-quarter of the original unpolarized intensity.

Final Answer: $I_0/4$

Answer: (A)

Go Back to Question 29

Q30.

Solution

Concept:

In a uniform gravitational field near the surface of the Earth, the gravitational potential energy of an object is a scalar position-dependent energy that represents the mechanical work performed against gravity to lift the object to a specific altitude relative to a chosen reference level.

Solution:

(a) The gravitational potential energy U of a mass m in a uniform gravitational field is defined by the linear work formula $U = mgh$, where g represents the constant acceleration due to gravity and h denotes the vertical height.

(b) This formula assumes that the reference level where the potential energy is defined to be zero ($U = 0$) is located exactly at the surface of the Earth.

(c) When an object is lifted vertically upward to an altitude h above this reference surface, mechanical work must be performed against the downward force of gravity ($F = mg$).

(d) The work required to move the object a vertical distance h at a constant speed is given by the product of the force and the displacement: $W = F \cdot h = mgh$.

(e) This performed mechanical work is stored within the gravitational field as potential energy. Because the object is positioned above the reference surface, its potential energy is positive and is expressed simply as $U = mgh$.

Final Answer: mgh

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept:

Fourier's law of thermal conduction establishes a fundamental mathematical framework that describes how heat energy flows through solid materials. This thermodynamic principle states that the time rate of linear heat transfer through a uniform slab depends directly on the geometry of the conductor and the spatial temperature gradient.

Solution:

(a) Fourier's law of heat conduction is expressed mathematically by the rate equation $\frac{Q}{t} = \frac{kA(T_H - T_C)}{L}$, where $\frac{Q}{t}$ represents the thermal power or rate of heat energy transferred through the solid material.

(b) In this formula, the constant parameter k represents the intrinsic thermal conductivity of the material, which quantifies its ability to conduct heat. The parameter L denotes the linear thickness or total length of the conducting path.

(c) The term $(T_H - T_C)$ represents the total temperature difference driving the thermal energy from the high-temperature hot zone to the low-temperature cold zone.

(d) The variable A represents the total cross-sectional area of the face through which the heat travels, oriented completely perpendicular to the direction of the thermal energy flow vector.

(e) Analyzing this mathematical formulation demonstrates that the overall rate of thermal conduction is directly proportional to both the driving temperature difference and the cross-sectional area. Therefore, increasing the cross-sectional area enhances the heat transfer rate.

Final Answer: Cross-sectional area

Answer: (B)

Go Back to Question 31

Q32.

Solution

Concept:

According to Biot-Savart law and the principles of magnetostatics, a steady electric current flowing through a circular loop of wire generates a localized magnetic field in the surrounding space. The magnitude of this magnetic field vector reaches a maximum value at the geometric center of the circular loop.

Solution:

(a) The Biot-Savart law states that the magnetic field contribution from an infinitesimal current element is given by $dB = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$, where μ_0 represents the absolute magnetic permeability of free space.

(b) For a perfect circular path of wire carrying a steady electric current I, every small current segment $d\vec{l}$ along the circumference is oriented perpendicular to the radial position vector pointing toward the center.

(c) Integrating these infinitesimal magnetic contributions along the entire circumference of a loop of radius r simplifies the vector cross product, as the angle is always ninety degrees.

(d) The total integration around the circular loop path yields the classic scalar expression for the central magnetic field: $B = \frac{\mu_0 I}{4\pi r^2}\int dl = \frac{\mu_0 I}{4\pi r^2}(2\pi r) = \frac{\mu_0 I}{2r}$.

(e) This formula demonstrates that the central magnetic field strength varies directly with the current magnitude I and inversely with the loop radius r.

Final Answer: $\mu_0 I \overline{2r}$

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept:
In classical mechanics, a perfectly elastic collision between two independent macroscopic bodies is governed simultaneously by the conservation of linear momentum and the conservation of total kinetic energy. Under specific mass configurations, these conservation laws lead to a complete exchange of velocities.

Solution:

(a) Consider a one-dimensional elastic collision where a moving particle of mass m_1 traveling with an initial velocity u_1 undergoes a head-on impact with a stationary second particle of mass m_2 ($u_2 = 0$).

(b) The final velocity formulas derived from the conservation laws are given by $v_1 = \frac{(m_1-m_2)u_1+2m_2u_2}{m_1+m_2}$ and $v_2 = \frac{(m_2-m_1)u_2+2m_1u_1}{m_1+m_2}$.

(c) The problem specifies that the two interacting bodies have completely identical physical masses, which means we can substitute the condition $m_1 = m_2 = m$ into these kinematic equations.

(d) Substituting $m_1 = m_2$ and $u_2 = 0$ into the first expression yields $v_1 = \frac{(m-m)u_1+0}{2m} = 0$, demonstrating that the initially moving object comes to a complete rest.

(e) Substituting these same parameters into the second expression yields $v_2 = \frac{0+2mu_1}{2m} = u_1$, showing that the stationary object departs with the exact velocity of the first.

Final Answer: The moving object stops and the stationary one moves

Answer: (B)

Go Back to Question 33

Q34.

Solution

Concept:
The total physical mass of a stable composite atomic nucleus is always strictly less than the sum of the individual rest masses of its constituent protons and neutrons. This missing mass, known as the mass defect, represents the energy released during the formation of the nucleus.

Solution:

(a) The structural difference in mass within a nucleus containing Z protons and N neutrons is defined as the mass defect: $\Delta m = (Zm_p + Nm_n) - M_{\text{nucleus}}$, where M_{nucleus} is the measured nuclear mass.

(b) According to Einstein's principle of mass-energy equivalence, mass and energy are interchangeable quantities related by the relativistic formula $E = \Delta m \cdot c^2$, where c is the speed of light.

(c) When free nucleons combine to form a stable bound nucleus, a portion of their total rest mass is converted into electromagnetic energy and radiated away from the system.

(d) The equivalent energy corresponding to this mass defect is called the nuclear binding energy, which measures the cohesive force holding the nucleus together.

(e) This physical transformation demonstrates that the fundamental origin of nuclear binding energy is the direct conversion of rest mass into thermal and radiative energy during nucleon aggregation.

Final Answer: Conversion of mass to energy

Answer: (B)

Go Back to Question 34

Q35.

Solution

Concept:
The optical power of a thin spherical lens is a quantitative physical parameter that measures its ability to converge or diverge incoming parallel light rays. This optical parameter is defined as the mathematical reciprocal of the focal length of the lens when measured in meters.

Solution:

(a) The mathematical relationship used to calculate the optical power of a lens is expressed by the algebraic equation $P = \frac{1}{f}$, where P represents the power and f denotes the focal length.

(b) When using this optical formula, the focal length of the lens must be expressed in standard SI units of meters (m) to obtain the power in Diopters (D).

(c) The problem provides the specific parameters for a converging lens, stating that its focal length is exactly $f = 0.25$ meters.

(d) Substituting this metric value into the reciprocal power equation yields the fractional expression $P = \frac{1}{0.25}$.

(e) Evaluating this fraction yields a value of $P = 4$. Because a positive focal length indicates a converging optical element, the power is exactly +4 Diopters (4 D).

Final Answer: 4 D

Answer: (A)

Go Back to Question 35

Q36.

Solution

Concept:
In classical thermodynamics, entropy is a fundamental state function that quantifies the degree of statistical disorder or randomness within a system. For a reversible thermodynamic process, the net change in system entropy is defined by the relationship between heat transfer and absolute temperature.

Solution:

(a) The fundamental thermodynamic definition of an infinitesimal change in entropy for a reversible process is given by the differential expression $dS = \frac{dQ_{\text{rev}}}{T}$.

(b) To find the total change in entropy ΔS for a finite thermodynamic process, integrate this differential relation between the initial and final states: $\Delta S = \int \frac{dQ_{\text{rev}}}{T}$.

(c) The problem specifies that the gas sample undergoes an isothermal state change. By definition, an isothermal process is one where the absolute thermodynamic temperature remains constant ($\Delta T = 0$).

(d) Because the temperature T is held constant throughout an isothermal process, it can be factored out of the integration, giving $\Delta S = \frac{1}{T} \int dQ_{\text{rev}}$.

(e) The total integral of the heat elements represents the net heat energy Q absorbed or rejected by the system. This yields the expression $\Delta S = \frac{Q}{T}$ for an isothermal process.

Final Answer: $\Delta S = Q/T$

Answer: (A)

Go Back to Question 36

Q37.

Solution

Concept:
When a charged particle moves through a magnetic field, it experiences a magnetic force known as the Lorentz force component. This vector interaction is governed by a vector cross product, which means the direction of the force is always perpendicular to the plane formed by the velocity and magnetic field vectors.

Solution:

(a) The magnetic force acting on a point charge q moving with an instantaneous velocity vector $\vec{v}$ inside a uniform magnetic field $\vec{B}$ is defined by the Lorentz force formula $\vec{F} = q(\vec{v} \times \vec{B})$.

(b) The geometric properties of a vector cross product dictate that the resulting product vector $\vec{F}$ must be perpendicular to both interacting vectors, $\vec{v}$ and $\vec{B}$, simultaneously.

(c) This means the magnetic force vector acts perpendicular to the instantaneous line of motion, altering the direction of the velocity vector without changing its speed.

(d) Because the force is always perpendicular to the velocity vector ($\vec{F} \cdot \vec{v} = 0$), the instantaneous mechanical work performed by the magnetic field on the charge is zero.

(e) Therefore, analyzing the geometric properties of the Lorentz force cross product shows that the magnetic force vector is always oriented perpendicular to both the field lines and the velocity vector.

Final Answer: Perpendicular to both field and velocity

Answer: (B)

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Q38.

Solution

Concept:
A simple pendulum consists of a localized point mass suspended from a rigid, frictionless pivot by a light, inextensible string. When displaced by a small angle from its vertical equilibrium alignment, the system undergoes simple harmonic motion with an oscillation period determined by its length and gravity.

Solution:

(a) Analyze the restoring torque acting on the pendulum bob when it is displaced by a small angle θ. The restoring torque is provided by gravity and is written as $\tau = -mgL\sin\theta$.

(b) Applying the small-angle approximation where $\sin\theta \approx \theta$ for angles under fifteen degrees simplifies the restoring torque expression to the linear form $\tau = -mgL\theta$.

(c) Equating this restoring torque to the rotational equation of motion gives $-mgL\theta = I\alpha$, where $I = mL^2$ is the moment of inertia of the point mass and α is the angular acceleration.

(d) Substituting the moment of inertia into the equation yields $-mgL\theta = (mL^2)\alpha$. Canceling common terms simplifies the expression to $\alpha = -\left(\frac{g}{L}\right)\theta$.

(e) This matches the standard harmonic equation $\alpha = -\omega^2\theta$, where the angular frequency is $\omega = \sqrt{\frac{g}{L}}$. The total time period T of a full oscillation is given by $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{L}{g}}$.

Final Answer: T = $2\pi\sqrt{L/g}$

Answer: (A)

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Q39.

Solution

Concept:
The Compton effect demonstrates the particle nature of electromagnetic radiation through the inelastic scattering of an incident high-energy photon by a stationary free electron. This quantum phenomenon involves a transfer of momentum and energy, which increases the wavelength of the scattered photon.
Solution:

(a) In a Compton scattering event, an incident photon carrying energy $E = h\nu$ and momentum $p = \frac{h}{\lambda}$ collides with an electron that is initially at rest.

(b) During this relativistic collision, the photon transfers a portion of its kinetic energy to the electron, causing the electron to recoil away from the impact site.

(c) Because the photon loses energy during the collision, its final energy E' must be strictly less than its initial energy $(E' < E)$.

(d) According to the wave relation $E = \frac{hc}{\lambda}$, the wavelength of an electromagnetic photon varies inversely with its total energy.

(e) Since the scattered photon has less energy than the incident photon, its wavelength must increase $(\lambda' > \lambda)$. The shifted wavelength is given by $\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$, meaning the scattered wavelength is always greater than the incident wavelength for non-zero scattering angles.

Final Answer: Greater than the incident wavelength

Answer: (B)

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Q40.

Solution

Concept:
An adiabatic process is a thermodynamic state transformation that occurs within a system without any exchange of heat energy or mass with the surrounding environment. For an ideal gas sample undergoing a reversible adiabatic process, the state variables are governed by Poisson's relations.

Solution:

(a) The first law of thermodynamics states that $dQ = dU + dW$. For an adiabatic process, there is no heat exchange with the surroundings, meaning the heat term is zero ($dQ = 0$).

(b) This condition simplifies the first law expression to $dU + dW = 0$. Substituting the ideal gas definitions $dU = nC_v dT$ and $dW = PdV$ yields $nC_v dT + PdV = 0$.

(c) Differentiating the ideal gas law ($PV = nRT$) and combining it with this simplified first law expression eliminates the temperature variable dT.

(d) This substitution leads to a differential equation relating pressure and volume: $\frac{dP}{P} + \gamma \frac{dV}{V} = 0$, where $\gamma = \frac{C_P}{C_v}$ represents the ratio of specific heats.

(e) Integrating this differential equation gives the classic adiabatic relation $PV^\gamma =$ constant. This equation describes how the pressure and volume of an ideal gas vary during an adiabatic process.

Final Answer: $\text{PV}^\gamma = \text{constant}$

Answer: (B)

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Answer Key

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