NIOS Class 12 Physics Sample Paper-7

Duration: 180 Minutes **Maximum Marks: 80**

Instructions

- This paper contains **43** Questions. The paper is divided into two sections: **Section A – 40** marks, **Section B – 40** marks.
- **Section A** consists of
  - **Q.No. 1 to 16** – Multiple Choice type questions (MCQs) carrying 1 mark each. Select and write the most appropriate option out of the four options given in each of these questions. An internal choice has been provided in some of these questions. You have to attempt only one of the given choices in such questions.
  - **Q. No. 17 to 28**– Objective-type questions. Q. No. 17 to 28 carry 02 marks each (with 2 sub- parts of 1 mark each). Attempt these questions as per the instructions given for each of the questions 17 –28.
- **Section B** consists of
  - **Q.No. 29 to 37** – Very Short questions carrying 02 marks each to be answered in the range of 30 to 50 words.
  - **Q.No. 38 to 41** – Short Answer type questions carrying 03 marks each to be answered in the range of 50 to 80 words.
  - **Q.No. 42 and 43** – Long Answer type questions carrying 05 marks each to be answered in the range of 80 to 120 words.
- There is **No Negative marking**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Section: A

Q1. A point charge $+q$ is placed at the centre of an uncharged hollow conducting sphere. The electric field at a point outside the sphere at distance r from the centre is: **(1)**

(A) Zero

(B) Same as that of a point charge $+q$ placed at the centre

(C) Half of that of a point charge $+q$

(D) Inversely proportional to r^3

Q2. A body of mass 2 kg moves with a uniform velocity of $5\,\mathrm{m\,s^{-1}}$ on a frictionless surface. The net force acting on the body is: **(1)**

(A) 10 N

(B) 2.5 N

(C) 0 N

(D) 0.4 N

Q3. In a single-slit diffraction experiment, if the slit width is increased, the width of the central maximum: **(1)**

(A) Increases

(B) Decreases

(C) Remains the same

(D) Becomes zero

Q4. The de Broglie wavelength associated with a particle is λ. If its momentum is doubled, its new wavelength becomes: **(1)**

(A) $\lambda/2$

(B) 2λ

(C) $\lambda/\sqrt{2}$

(D) $\sqrt{2}\,\lambda$

Q5. Three capacitors of $2\,\mu\mathrm{F}$ each are connected in series. The equivalent capacitance is: **(1)**

(A) $6\,\mu\mathrm{F}$

(B) $2\,\mu\mathrm{F}$

(C) $\frac{2}{3}\,\mu$F

(D) $3\,\mu$F

Q6. A rocket works on the principle of conservation of: **(1)**

(A) Energy

(B) Mass

(C) Linear momentum

(D) Angular momentum

Q7. Two points on a wave are separated by a distance $\lambda/2$. The phase difference between them is: **(1)**

(A) $\pi/2$

(B) π

(C) 2π

(D) $\pi/4$

Q8. During an isothermal expansion of an ideal gas, its internal energy: **(1)**

(A) Increases

(B) Decreases

(C) Remains unchanged

(D) First increases then decreases

Q9. The SI unit of magnetic flux is: **(1)**

(A) Tesla

(B) Weber

(C) Henry

(D) Ampere-meter

Q10. In a full-wave rectifier, the output frequency is: **(1)**

(A) Same as the input frequency

(B) Twice the input frequency

(C) Half the input frequency

(D) Zero

Q11. A motorcyclist moves in a vertical circle inside a hollow sphere of radius r. The minimum speed needed at the topmost point is: **(1)**

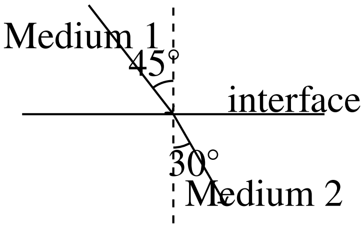
(A) $\sqrt{gr}$

(B) $\sqrt{2gr}$

(C) $\sqrt{gr/2}$

(D) $2\sqrt{gr}$

Q12. A ray of light is incident on a plane interface between two media as shown. If angle of incidence is 45° and angle of refraction is 30°, the refractive index of medium 2 w.r.t. medium 1 is: **(1)**



(A) $\sqrt{2}$

(B) $1/\sqrt{2}$

(C) 1

(D) 2

Q13. The fundamental frequency of a stretched string is f. If the tension is made four times, the fundamental frequency becomes: **(1)**

(A) $f/2$

(B) $2f$

(C) $4f$

(D) $f/4$

Q14. Two soap bubbles of radii r_1 and r_2 ($r_1 > r_2$) are in contact. The excess pressure inside the smaller bubble compared to the larger one is: **(1)**

(A) Less

(B) More

(C) Equal

(D) Zero

Q15. The energy released per fission of a uranium-235 nucleus is approximately: **(1)**

(A) 2 eV

(B) 200 eV

(C) 200 MeV

(D) 200 GeV

Q16. A solenoid of length 0.5 m has 500 turns and carries a current of 2 A. The magnetic field at its centre is ($\mu_0 = 4\pi \times 10^{-7}$ T m/A): **(1)**

(A) 2.51×10^{-3} T

(B) 1.26×10^{-3} T

(C) 5.02×10^{-3} T

(D) 0.63×10^{-3} T

Note: Q. No. 17 to 28 are the objective type questions of 2 marks each.

Q17. Read the passage given below and answer the following questions:

A cricket ball of mass 0.15 kg is moving horizontally at $30\,\mathrm{m\,s^{-1}}$. A fielder catches it and brings it to rest. By moving his hands backward, the fielder increases the time of catching and reduces the force on his hands. **(2)**

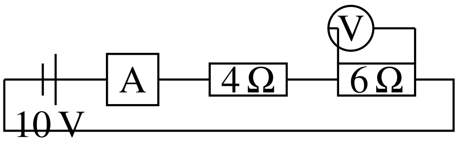
1. Calculate the impulse imparted to the fielder's hands.
2. If the ball is stopped in 0.1 s, what is the average force exerted on the hands?

Q18. Complete the following by using the options given below:
(diffraction, longitudinal, refraction, interference) **(2)**

1. The phenomenon of bending of light around the corners of obstacles is called . . . .
2. Sound waves in air are . . . . waves.

Q19. Read the passage and answer the questions that follow.

A student connects two resistors of $4\,\Omega$ and $6\,\Omega$ in series with a 10 V battery. A voltmeter is connected across the $6\,\Omega$ resistor and an ammeter in series with the battery. Internal resistance of the battery is negligible. **(2)**



1. What is the total resistance and current in the circuit?
2. What is the reading of the voltmeter across the $6\,\Omega$ resistor?

Q20. Fill in the blanks: **(2)**

1. In an adiabatic expansion of a gas, the temperature of the gas . . . .
2. The efficiency of a Carnot engine working between source temperature T_1 and sink temperature T_2 is $\eta =$ . . . .

Q21. Match the items in Column I with the most appropriate items in Column II: **(2)**

Column I	**Column II**
(a) Stokes' law	(i) Pressure applied at one point is transmitted equally
(b) Archimedes' principle	(ii) Loss in weight equals weight of displaced fluid
(c) Pascal's law	(iii) Viscous drag force $F = 6\pi\eta r v$
(d) Equation of continuity	(iv) $A_1 v_1 = A_2 v_2$

Q22. Fill in the blanks: **(2)**

1. In an n-type semiconductor, the majority charge carriers are ....
2. The energy band gap of silicon at room temperature is approximately . eV.

Q23. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement: **(2)**

1. The total energy of an electron in any Bohr orbit of the hydrogen atom is always negative.
2. The photoelectric effect can be fully explained by the wave theory of light.

Q24. Match the items in Column I with the most appropriate items in Column II: **(2)**

Column I	**Column II**
(a) Biot-Savart law	(i) $V = IR$
(b) Ampere's circuital law	(ii) $dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin\theta}{r^2}$
(c) Lorentz force	(iii) $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$
(d) Ohm's law	(iv) $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enc}}$

Q25. Fill in the blanks: **(2)**

1. The splitting of white light into its constituent colours by a prism is called .
2. The resolving power of a microscope . . with increase in the wavelength of light used.

Q26. Match the items in Column I with the most appropriate items in Column II: **(2)**

Column I	**Column II**
(a) Elastic collision	(i) Point where entire mass can be assumed to be concentrated
(b) Inelastic collision	(ii) Both momentum and kinetic energy conserved
(c) Impulse	(iii) Only momentum conserved, KE not conserved
(d) Centre of mass	(iv) Product of force and time interval

Q27. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement: **(2)**

1. The magnetic field inside a long solenoid is uniform and parallel to the axis.
2. A charged particle moving parallel to a magnetic field experiences maximum force.

Q28. Match the items in Column I with the most appropriate items in Column II: **(2)**

Column I	**Column II**
(a) n-type semiconductor	(i) Trivalent dopant (e.g., boron)
(b) p-type semiconductor	(ii) Pentavalent dopant (e.g., arsenic)
(c) Forward bias	(iii) Depletion layer becomes wider
(d) Reverse bias	(iv) Depletion layer becomes narrower

Section: B

Q29. Define interference of light. State the condition for constructive interference in terms of path difference. **(2)**

Q30. A force of 15 N acts on a body of mass 3 kg initially at rest for 4 seconds. Find the velocity acquired and the distance covered in this time. **(2)**

Q31. (i) State Ohm's law. Write its mathematical form and mention one limitation.

OR

(ii) Three resistors of $2\,\Omega$, $4\,\Omega$ and $8\,\Omega$ are connected in parallel. Find the equivalent resistance. **(2)**

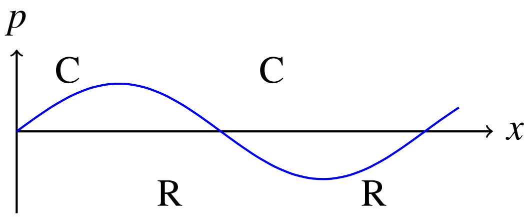
Q32. (i) Define refractive index of a medium. How is it related to the speed of light?

OR

(ii) What is total internal reflection? State two conditions necessary for it to occur. **(2)**

Q33. Two cells of emf $1.5\,\text{V}$ and $2.0\,\text{V}$ with internal resistances $0.5\,\Omega$ and $1.0\,\Omega$ respectively are connected in series (aiding) with an external resistance of $6.5\,\Omega$. Find the current in the circuit and the potential difference across the external resistance. **(2)**

Q34. A tuning fork of frequency $340\,\text{Hz}$ produces sound waves in air. If the speed of sound is $340\,\text{m}\,\text{s}^{-1}$, find the wavelength. Draw a diagram showing compressions (C) and rarefactions (R). **(2)**



Q35. (i) Write Einstein's photoelectric equation and explain each term.

OR

(ii) Define nuclear fission. Give one example and state one application. **(2)**

Q36. A soap bubble has a radius of $2\,\text{cm}$. If the surface tension of the soap solution is $0.03\,\text{N}\,\text{m}^{-1}$, calculate the excess pressure inside the soap bubble. What would be the excess pressure if it were an air bubble inside water (single surface) of the same radius? **(2)**

Q37. Two moles of an ideal gas expand isothermally from $2\,\text{L}$ to $8\,\text{L}$ at $300\,\text{K}$. Calculate the work done by the gas. ($R = 8.314\,\text{J}\,\text{mol}^{-1}\,\text{K}^{-1}$) **(2)**

Q38. Define the following terms with one example each:

A. Extrinsic semiconductor

B. Zener diode

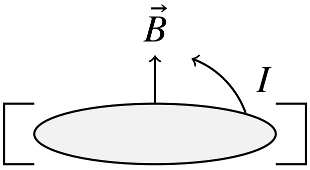
C. Transistor **(3)**

Q39. (i) In a single-slit diffraction experiment, the slit width is 0.1 mm and the screen is 2 m away. If light of wavelength 500 nm is used, find the width of the central maximum.

OR

(ii) A concave mirror has focal length 15 cm. An object 3 cm tall is placed at 20 cm from the mirror. Find the position, nature and size of the image. **(3)**

Q40. State Biot-Savart law. A circular coil of radius 7 cm has 100 turns and carries a current of 0.5 A. Calculate the magnetic field at the centre. ($\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T\,m/A}$) **(3)**



circular coil

Q41. (i) A ball of mass 0.2 kg is thrown vertically upward with speed $20\,\mathrm{m\,s^{-1}}$. Using the work-energy theorem, calculate the maximum height reached. ($g = 10\,\mathrm{m\,s^{-2}}$)

OR

(ii) A truck of mass 2000 kg moving at $10\,\mathrm{m\,s^{-1}}$ collides with a stationary car of mass 1000 kg. After collision they move together. Find their common velocity and the kinetic energy lost. **(3)**

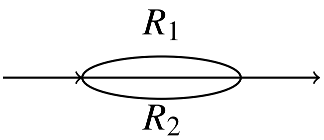
Q42. (i) (a) Derive the lens maker's formula for a thin convex lens: $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

(b) State the laws of photoelectric emission.

OR

(ii) (a) Explain diffraction of light at a single slit and derive the condition for minima: $a \sin\theta = n\lambda$.

(b) Calculate the binding energy per nucleon of ${}^{4}_{2}\mathrm{He}$. Given: $m_p = 1.00728\,\mathrm{u}$, $m_n = 1.00867\,\mathrm{u}$, $m_{\mathrm{He}} = 4.00260\,\mathrm{u}$, $1\,\mathrm{u} = 931.5\,\mathrm{MeV/c^2}$. **(5)**



Q43. (i) (a) A bullet of mass 10 g moving at $400\,\mathrm{m\,s^{-1}}$ embeds itself in a wooden block of mass 0.99 kg at rest on a smooth surface. Find the velocity after collision.

(b) State the first law of thermodynamics with one example.

(c) What is Doppler effect? Give one application.

(d) Draw the V-I characteristics of a p-n junction diode in forward bias.

OR

(ii) (a) A crane lifts a 500 kg load to a height of 20 m in 25 s. Calculate the power. ($g = 10\,\mathrm{m\,s^{-2}}$)

(b) State the second law of thermodynamics (Kelvin–Planck statement).

(c) Distinguish between transverse and longitudinal waves with one example each.

(d) Draw the circuit symbol of an n-p-n transistor. **(5)**

Detailed Solutions

Q1.

Solution

Concept: According to Gauss's law, the net electric flux escaping through any closed Gaussian surface depends exclusively on the total net enclosed electric charge. When an isolated point charge $+q$ is positioned exactly at the geometric center of a hollow conducting spherical shell, a negative charge $-q$ is uniformly induced on the internal surface of the shell via electrostatic induction, which simultaneously leaves an equal positive charge $+q$ spread uniformly over its exterior boundary. The resulting electric field profile outside the shell matches the radial field of an isolated point charge.

Step 1: Placing the discrete point charge $+q$ at the center causes an immediate separation of mobile charge carriers within the conductor, drawing an induced charge of $-q$ to the inner cavity wall and repelling $+q$ to the outer surface.
Step 2: To evaluate the electric field strength at an external radial distance r from the center, we construct a concentric spherical Gaussian surface. Applying Gauss's law yields the integral equation $\oint \vec{E} \cdot d\vec{A} = q/\varepsilon_0$.
Step 3: Due to spherical symmetry, the electric field vector is constant and directed radially outward, simplifying the expression to $E(4\pi r^2) = q/\varepsilon_0$, which gives $E = kq/r^2$.
Final Answer: Same as that of a point charge +q placed at the centre

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: Newton's first law of motion asserts that an object will sustain its state of rest or preserve its uniform linear motion along a straight path unless compelled to modify that state by an external net unbalanced force. Moving with a uniform or constant velocity implies that the speed and direction are unchanged over time, which means the instantaneous linear acceleration vector of the body is zero, resulting in zero net force.

Step 1: The problem states that the object, which has a constant mass of $m = 2\,\mathrm{kg}$, travels continuously with a constant, uniform linear velocity of $v = 5\,\mathrm{m\,s^{-1}}$. Because the velocity vector does not change over time, the net translational acceleration is $a = 0\,\mathrm{m\,s^{-2}}$.
Step 2: Applying Newton's second law of motion allows us to compute the required force directly by taking the product of mass and acceleration, leading to the expression: $F_{\mathrm{net}} = ma$.
Step 3: Substituting the parameters yields: $F_{\mathrm{net}} = 2\,\mathrm{kg} \times 0\,\mathrm{m\,s^{-2}} = 0\,\mathrm{N}$. This mathematically confirms that no net external force is required to sustain steady, unaccelerated motion through space.
Final Answer: $0\,\mathrm{N}$

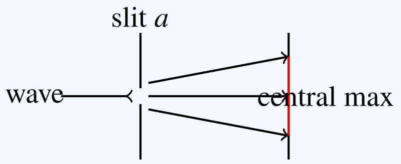
Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept: In wave optics, the physical phenomenon of single-slit diffraction occurs when a coherent wavefront encounters a narrow opening. The total angular or linear spatial width of the central bright maximum formed on a distant observation screen is governed by the expression $w = 2D\lambda/a$. This mathematical relation demonstrates that the width of the central maximum is inversely proportional to the physical width of the slit opening (a).



Step 1: The formula dictates that the physical parameters of the central diffraction peak are heavily modulated by the aperture dimensions. If the physical slit width a is gradually increased, the angular spreading of the diffracted rays is suppressed.
Step 2: Because the denominator value in the core relation $w = 2D\lambda/a$ increases while the wavelength λ and screen distance D remain constant, the overall spatial width w must decrease, sharpening the central bright fringe.
Final Answer: Decreases

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: The de Broglie hypothesis asserts that moving matter particles exhibit wave-like characteristics, where the corresponding de Broglie wavelength is defined by the mathematical ratio $\lambda = h/p$. In this fundamental quantum expression, h represents Planck's constant and p denotes the linear momentum of the moving particle. This shows that the particle's wavelength is inversely proportional to its momentum.

Step 1: The initial physical state of the moving particle establishes a baseline de Broglie wavelength that is inversely proportional to its momentum, given by the expression $\lambda = h/p$.
Step 2: The problem states that the momentum of the particle undergoes an adjustment, doubling its original value to yield a new momentum parameter of $p' = 2p$.
Step 3: Substituting this modified momentum value into the de Broglie equation gives the new matter wavelength: $\lambda' = h/p' = h/(2p) = \frac{1}{2}(h/p) = \lambda/2$. This confirms that doubling the momentum halves the wavelength.
Final Answer: $\lambda/2$

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: When multiple independent electrostatic capacitors are wired together in a series combination, the same electrical charge accumulates across each individual plate. The reciprocal of the net equivalent capacitance of the entire network is calculated by summing the individual reciprocal values of each component, given by $1/C_{eq} = 1/C_1 + 1/C_2 + 1/C_3$.

Step 1: The problem specifies a circuit configuration containing three identical capacitors connected in series, where each individual component has a capacitance value of $C_1 = C_2 = C_3 = 2\,\mu\text{F}$.
Step 2: Substituting these values into the reciprocal formula yields: $1/C_{eq} = 1/2 + 1/2 + 1/2 = 3/2\,\mu\text{F}^{-1}$. This calculation determines the inverse value of the total capacity.
Step 3: Inverting this fraction yields the equivalent capacitance value for the series network: $C_{eq} = 2/3\,\mu\text{F}$. This value is smaller than the capacitance of any single component in the combination.
Final Answer: $\frac{2}{3}\,\mu\text{F}$

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept: Rocket propulsion operates on the law of conservation of linear momentum, which states that the total momentum of an isolated system remains constant over time when no net external forces act on it. As a rocket fires, its engines forcefully eject hot exhaust gases backward, generating a forward reaction momentum.

Step 1: The combined system consisting of the structural rocket body and its internal fuel load can be treated as an isolated physical system, meaning its total net linear momentum must be conserved throughout the flight.
Step 2: Initially, the total momentum is zero. When the engines ignite and eject combustion gases backward with a momentum of $-p$, the rocket mass must gain an equal and opposite forward momentum of $+p$ to keep the total momentum balanced.
Final Answer: Conservation of linear momentum

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept: In wave mechanics, the phase difference between two points on a coherent wave profile is related to their spatial path difference by the formula: Phase Difference $= (2\pi/\lambda) \times$Path Difference. This relationship shows that traveling a linear distance equal to one complete wavelength λ corresponds to a full angular rotation of 2π radians.

Step 1: The problem states that the spatial path difference between two interfering light waves at a specific observation point is equal to exactly half a wavelength, written as $\Delta x = \lambda/2$.
Step 2: Substituting this path difference into the conversion equation yields: $\Delta\phi = (2\pi/\lambda) \times (\lambda/2)$. This allows us to find the corresponding angular offset between the two waves.
Step 3: Simplifying the expression by canceling out the common wavelength variable λ and the factor of two results in: $\Delta\phi = \pi$ radians. This phase shift corresponds to destructive interference.
Final Answer: π

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: The internal energy of an ideal gas depends exclusively on its absolute thermodynamic temperature ($U \propto T$). This occurs because an ideal gas model assumes there are no intermolecular forces or potential energy interactions between the gas particles, meaning its internal energy consists entirely of temperature-dependent kinetic energy.

Step 1: By definition, an isothermal thermodynamic process is a transformation during which the absolute temperature of the working gas system is kept perfectly constant throughout the cycle, meaning $T_1 = T_2$, or $\Delta T = 0$.
Step 2: Because the internal thermal energy U depends solely on the temperature parameter, keeping the temperature constant means the net change in internal energy must be zero ($\Delta U = 0$). Thus, the internal energy remains unchanged.
Final Answer: Remains unchanged

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept: Magnetic flux (Φ_B) measures the total magnetic field passing through a given surface area, defined mathematically by the vector dot product equation $\Phi_B = \vec{B} \cdot \vec{A} = BA\cos\theta$. The standard SI unit used to quantify magnetic flux is the weber (Wb), which can be expressed in base units as $1\,\text{Wb} = 1\,\text{T}\,\text{m}^2$.

Step 1: Reviewing standard electromagnetic units reveals that the tesla (T) is the unit of magnetic flux density B, and the henry (H) is the unit of electrical inductance.
Step 2: The weber (Wb) is the standard international unit used to measure magnetic flux. It represents the total flux produced by a magnetic field of one tesla passing perpendicularly through a surface area of one square meter.
Final Answer: Weber

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: An electronic full-wave rectifier converts alternating current (AC) into direct current (DC) by routing both the positive and negative half-cycles of the input waveform through a diode bridge. This process redirects the current so it always flows in the same direction through the output load resistor.

Step 1: During a single complete cycle of the input alternating voltage wave, the full-wave rectifier processes the positive half-cycle and then inverts the negative half-cycle, producing two distinct output voltage pulses.
Step 2: Because the rectifier produces two output pulses for every single input cycle, the frequency of the rectified output signal is exactly twice that of the original input signal ($f_{\text{out}} = 2f_{\text{in}}$).
Final Answer: Twice the input frequency

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: For an object performing uniform circular motion in a vertical plane, it must maintain a critical velocity at the apex of its trajectory to prevent falling. At the top of the vertical loop, both the downward gravitational force and the downward normal reaction force provide the necessary centripetal acceleration, expressed as $mg + N = mv^2/r$. To find the absolute minimum allowable speed required to successfully complete the circular path without dropping, the normal contact force must reach its limiting value, meaning $N = 0$.

Step 1: Setting the normal reaction force to zero at this critical boundary condition reduces the dynamic balancing equation to $mg = mv^2/r$. This indicates that gravity alone sustains the centripetal acceleration at the highest point.
Step 2: To solve for the minimum threshold velocity, we cancel the mass m from both sides of the expression, which yields $g = v^2/r$. Multiplying by the radius gives $v^2 = gr$.
Step 3: Taking the square root of both sides gives the standard equation for the minimum threshold speed: $v = \sqrt{gr}$. Any speed below this value causes the object to lose contact and fall.
Final Answer: $\sqrt{gr}$

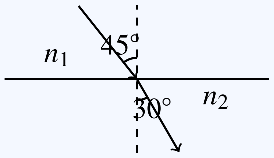
$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 11

Q12.

Solution

Concept: The physical phenomenon of refraction at a flat boundary between two different media is described by Snell's law, written as $n_1 \sin i = n_2 \sin r$. The relative refractive index of the second medium with respect to the first medium is defined as the ratio of their absolute refractive indices, which can be computed directly using the ratio of the sines of the angles: ${}_1n_2 = n_2/n_1 = \sin i/\sin r$.



Step 1: Examining the provided ray diagram, the measured angle of incidence in the first medium is $i = 45°$, while the corresponding angle of refraction inside the second medium is $r = 30°$.
Step 2: Substituting these specific angular parameters into the relative index formula gives the expression: ${}_1n_2 = \sin 45°/\sin 30°$.
Step 3: Using standard trigonometric values, $\sin 45° = 1/\sqrt{2}$ and $\sin 30° = 1/2$. Substituting these values gives ${}_1n_2 = (1/\sqrt{2})/(1/2) = 2/\sqrt{2} = \sqrt{2}$.
Final Answer: $\sqrt{2}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 12

Q13.

Solution

Concept: The fundamental frequency of oscillation for a flexible string that is clamped securely at both ends is determined by its physical length, its internal mechanical tension, and its linear mass density. This relationship is defined by the classical wave mechanics formula $f = (1/2L)\sqrt{T/\mu}$. Assuming that the length L and the linear mass density μ remain perfectly constant, the fundamental frequency is directly proportional to the square root of the applied tension, expressed as $f \propto \sqrt{T}$.

Step 1: The problem states that the internal tension within the vibrating string is increased to four times its baseline value, which gives a new tension parameter of $T' = 4T$.
Step 2: To determine the updated fundamental frequency f', we substitute the new tension parameter into the proportionality relationship, which yields the expression: $f' \propto \sqrt{4T}$.
Step 3: Factoring out the constant multiplier from the square root yields: $f' \propto 2\sqrt{T}$. Since the original frequency was proportional to $\sqrt{T}$, this shows that the new frequency is exactly double the initial value ($f' = 2f$).
Final Answer: 2f

Answer: (B)
Go Back to Question 13

Q14.

Solution

Concept: The internal pressure within a spherical soap bubble exceeds the external atmospheric pressure due to the surface tension forces acting along its dual fluid interfaces. This excess pressure is quantified by the classical Laplace equation for a fluid sphere: $\Delta P = 4\gamma/r$, where γ represents the surface tension and r is the radius. This formula shows that the excess pressure is inversely proportional to the radius ($\Delta P \propto 1/r$), meaning a smaller radius leads to a higher internal pressure.

Step 1: We are given two distinct soap bubbles of unequal dimensions. The smaller bubble has a radius r_2 that is less than the radius r_1 of the larger bubble, which is written mathematically as $r_2 < r_1$.
Step 2: Writing out the excess pressure expressions for both configurations yields $\Delta P_1 = 4\gamma/r_1$ for the large bubble and $\Delta P_2 = 4\gamma/r_2$ for the small bubble.
Step 3: Because the radius appears in the denominator, the smaller bubble accumulates a higher internal concentration of pressure, meaning $\Delta P_2 > \Delta P_1$. Therefore, the smaller bubble has more excess pressure.
Final Answer: More

Answer: (B)
Go Back to Question 14

Q15.

Solution

Concept: The induced nuclear fission of a heavy actinide nucleus, such as uranium-235 (^{235}U), is a highly energetic nuclear process initiated by thermal neutron capture. This interaction splits the unstable compound nucleus into lighter fission fragments and free neutrons. The immense energy released during this nuclear event stems from a net mass defect between the initial reactants and final products, which is converted to kinetic energy via Einstein's mass-energy equivalence principle, $E = \Delta mc^2$.

Step 1: Calculating the binding energy differences between the heavy parent nucleus and the more stable intermediate fission fragments reveals a significant net mass loss during rearrangement.
Step 2: In a standard fission event involving a single uranium-235 nucleus, this mass defect releases approximately 200 MeV of energy.
Step 3: This value far exceeds standard chemical reaction energies, which typically involve only a few electron volts (eV) per molecule. This massive energy release forms the operational foundation of nuclear power reactors.
Final Answer: 200 MeV

Answer: (C)

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Q16.

Solution

Concept: The axial magnetic field generated inside the central core of an infinitely long, tightly wound helical solenoid carrying a steady direct current is uniform and independent of the radial position. This magnetic flux density is given by Ampere's law as $B = \mu_0 nI$, where μ_0 is the permeability of free space, I is the electrical current, and $n = N/L$ is the number of turns per unit length.

Step 1: The problem provides a solenoid with $N = 500$ turns, a length of $L = 0.5$ m, and a current of $I = 2$ A. First, we calculate the turn density: $n = 500/0.5 = 1000$ turns/m.
Step 2: Next, we substitute this turn density and the free space permeability constant ($\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T\,m\,A^{-1}}$) into the magnetic field equation: $B = (4\pi \times 10^{-7}) \times 1000 \times 2 = 8\pi \times 10^{-4}$ T.
Step 3: To find the numerical value, we use the approximation $\pi \approx 3.1416$, which yields: $B = 8 \times 3.1416 \times 10^{-4} = 2.51 \times 10^{-3}$ T. This measures the strength of the magnetic field in the core.
Final Answer: 2.51×10^{-3} T

Answer: (A)

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Q17.

Solution

Concept: The impulse-momentum theorem states that the mechanical impulse $\vec{J}$ delivered to an object by a net external force is equal to the net change in its linear momentum. This relationship is expressed by the kinematic formula $\vec{J} = \vec{F}_{\text{avg}}\Delta t = \Delta\vec{p} = m(\vec{v}_f - \vec{v}_i)$. This allows us to calculate the average force exerted during a brief collision if the contact duration Δt is known.

Step 1: The problem provides the following parameters for a moving object: a mass of $m = 0.15\,\text{kg}$, an initial velocity of $v_i = 30\,\text{m}\,\text{s}^{-1}$, and a final velocity of $v_f = 0\,\text{m}\,\text{s}^{-1}$ upon coming to rest.
Step 2: Calculating the magnitude of the linear impulse yields: $J = |m(v_f - v_i)| = |0.15 \times (0 - 30)| = 4.5\,\text{N}\,\text{s}$. This represents the total momentum transferred during the collision.
Step 3: The problem states that the collision occurs over a brief time interval of $\Delta t = 0.1\,\text{s}$. Rearranging the impulse equation allows us to find the average force: $F_{\text{avg}} = J/\Delta t = 4.5/0.1 = 45\,\text{N}$.
Final Answer: Impulse = 4.5 N s; Average force = 45 N

Answer: (See above)

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Q18.

Solution

Concept: This problem addresses fundamental concepts in wave mechanics, specifically wave propagation and wave classification based on particle displacement. The bending of a wavefront around sharp boundaries or obstacles is called diffraction, while waves are classified as longitudinal if the medium particles vibrate parallel to the direction of wave travel.

Step 1: When a traveling light or sound wave encounters a sharp edge, obstacle, or narrow aperture comparable in size to its wavelength, it bends into the geometric shadow region. This distinctive wave behavior is defined as diffraction.
Step 2: In mechanical waves, waves are categorized by the orientation of their oscillations relative to the energy path. Sound waves traveling through an open air medium force the gas molecules to vibrate back and forth along the same axis as the wave propagation, making them longitudinal waves.
Final Answer: diffraction; longitudinal

Answer: (See above)

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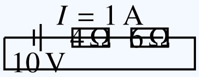
Q19.

Solution

Concept: In a single-loop series electrical circuit, charge conservation requires that the exact same electrical current flows through every connected component. The total equivalent resistance of a series network is the sum of the individual resistances ($R_{\text{total}} = R_1 + R_2$). The circuit current can be found using Ohm's law ($I = V/R_{\text{total}}$), and the voltage drop across any individual resistor is given by $V_R = IR$.



Step 1: The schematic shows a 10 V DC source connected to two series resistors with values of $R_1 = 4\,\Omega$ and $R_2 = 6\,\Omega$. The total equivalent resistance is: $R_{\text{total}} = 4 + 6 = 10\,\Omega$.
Step 2: Applying Ohm's law, the steady-state current flowing through the loop is: $I = 10\,\text{V}/10\,\Omega = 1\,\text{A}$.
Step 3: A voltmeter connected across the $6\,\Omega$ resistor measures its local potential drop. Using Ohm's law gives: $V_2 = I \times R_2 = 1\,\text{A} \times 6\,\Omega = 6\,\text{V}$.
Final Answer: R = $10\,\Omega$, $I = 1\,\text{A}$; $Voltmeter = 6\,\text{V}$

Answer: (See above)

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Q20.

Solution

Concept: An adiabatic expansion occurs when a thermodynamic gas system expands against external surroundings without exchanging heat energy with the environment ($Q = 0$). According to the first law of thermodynamics, the gas must perform expansion work entirely at the expense of its own internal thermal energy, which lowers the system temperature. The efficiency of a reversible Carnot engine operating between two thermal reservoirs depends solely on these absolute temperatures, given by $\eta = 1 - T_2/T_1$.

Step 1: In an adiabatic expansion, setting $Q = 0$ in the first law expression yields $\Delta U = -W$. Because the gas performs positive work during expansion ($W > 0$), the net change in internal energy must be negative ($\Delta U < 0$), which causes the gas temperature to decrease.
Step 2: The thermodynamic efficiency limit for a ideal Carnot heat engine cycle working between a hot source T_1 and a cold sink T_2 is determined using the absolute temperature ratio: $\eta = 1 - T_2/T_1$, where both temperatures must be expressed in Kelvin.
Final Answer: decreases; 1 - T_2/T_1

Answer: (See above)

Go Back to Question 20

Q21.

Solution

Concept: This section connects fundamental fluid mechanics concepts through matched physical equations. Stokes' law calculates the retarding viscous drag force acting on a small spherical particle falling through a fluid medium ($F = 6\pi\eta rv$). Archimedes' principle dictates that the upward buoyant force equals the total weight of the fluid displaced by a submerged body. Pascal's law states that external static pressure applied to a fluid is transmitted equally in all directions. The equation of continuity asserts that for steady, incompressible fluid flow, the volume flow rate remains constant across varying cross-sections ($A_1v_1 = A_2v_2$).

Step 1: Matching (a) with (iii): Stokes' law explicitly establishes that the viscous drag force acting against a sphere is directly proportional to its radius, its terminal velocity, and the fluid's dynamic viscosity.
Step 2: Matching (b) with (ii): Archimedes' principle describes the upward buoyant force acting on a fully or partially submerged object, stating that this force matches the weight of the fluid pushed aside.
Step 3: Matching (c) with (i): Pascal's law provides the foundational principle for hydraulic machinery, showing that pressure changes are transmitted undiminished throughout an enclosed fluid.
Step 4: Matching (d) with (iv): The continuity equation applies mass conservation to fluid dynamics, showing that fluid velocity increases where a pipe narrows.
Final Answer: (a)–(iii), (b)–(ii), (c)–(i), (d)–(iv)

Answer: (See above)

Go Back to Question 21

Q22.

Solution

Concept: In solid-state physics, an extrinsic n-type semiconductor is fabricated by introducing trace amounts of pentavalent impurity atoms into a pure tetravalent crystalline semiconductor lattice. Because these dopant atoms contain five valence electrons, four of them form covalent bonds with adjacent host atoms, leaving one loosely bound electron that easily dissociates to become a free charge carrier. Additionally, the characteristic forbidden energy band gap (E_g) of electronic-grade silicon determines its thermal activation properties and defines the minimum energy required to excite an electron.

Step 1: In an n-type semiconductor material, the majority charge carriers responsible for electrical conduction are free electrons. These are supplied by the donor impurities, while minority carriers are holes generated by thermal energy.

Step 2: The intrinsic band gap energy separating the valence band from the conduction band in silicon is approximately 1.1 eV at room temperature. This specific threshold requires incoming photons or thermal excitations to possess at least this amount of energy to promote electrons into the conduction band.

Final Answer: electrons; 1.1

Answer: (See above)

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Q23.

Solution

Concept: According to the Bohr model of atomic structure, the total electronic energy of an electron orbiting within a stable hydrogenic shell is given by the expression $E = -13.6/n^2$ eV. The negative sign indicates that the electron is in a bound state within the electrostatic potential well of the nucleus. In quantum optics, the photoelectric effect demonstrates the particle-like nature of light. Classical wave theory fails to explain this effect because it predicts that electron emission depends on wave intensity rather than a threshold frequency.

Step 1: The mathematical expression $E = -13.6/n^2$ eV yields a negative value for all valid principal quantum integers ($n = 1, 2, 3, \ldots$). This confirms that the electron remains bound to the nucleus, making the first statement TRUE.

Step 2: Classical wave theory assumes that continuous wave energy accumulates over time, predicting that high-intensity light should trigger electron emission regardless of frequency. However, experiments show that emission depends strictly on a minimum threshold frequency, which can only be explained using Einstein's discrete photon model. Therefore, the second statement is FALSE.

Final Answer: T; F

Answer: (See above)

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Q24.

Solution

Concept: This problem matches foundational electrodynamic principles with their mathematical laws. The Biot-Savart law calculates the differential magnetic flux density vector (dB) produced by an isolated, current-carrying element. Ampere's circuital law states that the line integral of a magnetic field along a closed loop is proportional to the enclosed net current. The Lorentz force equation describes the net mechanical force acting on a moving charge in combined fields. Ohm's law defines the linear relationship between voltage and current.

Step 1: Matching (a) with (ii): The Biot-Savart law mathematically describes the magnetic field generated by a current element, given by the inverse-square formulation: $dB = (\mu_0/4\pi)(I\,dl\sin\theta/r^2)$.
Step 2: Matching (b) with (iv): Ampere's circuital law calculates symmetric magnetic fields by setting the closed line integral equal to the enclosed current: $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{\text{enc}}$.
Step 3: Matching (c) with (iii): The Lorentz equation determines the net force experienced by a charge moving through space containing both electric and magnetic fields: $\vec{F} = q(\vec{E} + \vec{v}\times\vec{B})$.
Step 4: Matching (d) with (i): Ohm's law describes electrical resistance in a linear conductor, establishing that the potential drop across the component is proportional to the current: $V = IR$.
Final Answer: (a)–(ii), (b)–(iv), (c)–(iii), (d)–(i)

Answer: (See above)

Go Back to Question 24

Q25.

Solution

Concept: In wave optics, optical dispersion is the phenomenon where a beam of composite white light splits into its individual spectral colors when passing through a material medium with non-parallel faces, such as a glass prism. This occurs because the refractive index of the medium varies with the wavelength of the incident light. Additionally, the resolving power (R) of an optical instrument measures its ability to distinguish closely spaced objects, a property that is inversely proportional to the operating wavelength ($R \propto 1/\lambda$).

Step 1: When white light enters an optical prism, different wavelengths travel at different speeds through the glass. This variation in refractive index causes the constituent wavelengths to bend at slightly different angles, splitting the composite beam into a color spectrum through dispersion.
Step 2: The resolving power of an optical system is limited by wave diffraction and is inversely proportional to the wavelength of light used ($R \propto 1/\lambda$). Because of this inverse relationship, using longer wavelengths reduces the instrument's resolving power, while shorter wavelengths improve it.
Final Answer: dispersion; decreases

Answer: (See above)

Go Back to Question 25

Q26.

Solution

Concept: This mechanical problem focuses on momentum conservation, kinetic energy relationships, and system dynamics during collisions. In a perfectly elastic collision, both the total linear momentum and the total kinetic energy of the system are conserved. In an inelastic collision, the total linear momentum is conserved, but some kinetic energy is lost to internal work or thermal dissipation. Mechanical impulse represents the net change in momentum over a time interval, while the center of mass provides a single point representing the weighted average position of a distributed mass system.

Step 1: Matching (a) with (ii): A perfectly elastic collision represents an ideal interaction where kinetic energy and momentum are both conserved before and after the impact.
Step 2: Matching (b) with (iii): An inelastic collision conserves total momentum due to the absence of external forces, but converts a portion of the system's kinetic energy into thermal energy or structural deformation.
Step 3: Matching (c) with (iv): Impulse measures the effect of a force acting over time, calculated as the product of the average force and the contact duration: $J = F\Delta t$.
Step 4: Matching (d) with (i): The center of mass simplifies multi-body mechanics by tracking the mass-weighted average position of all particles in the system.
Final Answer: (a)–(ii), (b)–(iii), (c)–(iv), (d)–(i)

Answer: (See above)

Go Back to Question 26

Q27.

Solution

Concept: Ampere's law dictates that the magnetic field generated inside the central core of an infinitely long, tightly wound helical solenoid is highly uniform and directed parallel to its central longitudinal axis. The magnetic magnetic Lorentz force experienced by an electrically charged particle moving through a magnetic field depends on its velocity and the field vector, described by the cross-product equation $\vec{F} = q(\vec{v} \times \vec{B})$. This force varies with the angle between the two vectors, vanishing when they are parallel.

Step 1: Inside a long solenoid, the magnetic field lines run parallel to the central axis, creating a uniform field strength deep within the core. This makes the first statement TRUE.
Step 2: The magnetic force magnitude is given by $F = qvB\sin\theta$. When a charge is projected along the solenoid's axis, its velocity vector runs parallel to the magnetic field lines ($\theta = 0°$). Since $\sin 0° = 0$, the cross product vanishes and the net magnetic force is zero. Peak deflection force occurs when the particle moves perpendicular to the field lines ($\theta = 90°$). This makes the second statement FALSE.
Final Answer: T; F

Answer: (See above)

Go Back to Question 27

Q28.

Solution

Concept: This problem focuses on semiconductor electronics, specifically material doping profiles and the behavior of p-n junctions under external electrical bias. An extrinsic n-type semiconductor is formed by introducing pentavalent donor impurities, such as arsenic, while a p-type semiconductor is created using trivalent acceptor impurities, such as boron. Applying an external forward-bias voltage opposes the internal built-in potential barrier, narrowing the depletion region. Conversely, a reverse-bias voltage reinforces this internal barrier, widening the depletion region.

Step 1: Matching (a) with (ii): An n-type semiconductor requires a pentavalent dopant like arsenic, which provides extra free electrons to serve as the majority charge carriers.
Step 2: Matching (b) with (i): A p-type semiconductor requires a trivalent dopant like boron, which creates electron vacancies or holes that act as the majority charge carriers.
Step 3: Matching (c) with (iv): Connecting a p-n junction in a forward-bias configuration lowers the internal potential barrier, which narrows the depletion layer and allows current to flow easily.
Step 4: Matching (d) with (iii): Applying a reverse-bias voltage pulls mobile charge carriers away from the junction, widening the depletion layer and blocking current flow.
Final Answer: (a)–(ii), (b)–(i), (c)–(iv), (d)–(iii)

Answer: (See above)

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Q29.

Solution

Concept: In wave optics, optical interference is the physical phenomenon where two or more coherent light waves overlap in space, redistributing the total energy to form a pattern of alternating bright and dark fringes. For constructive interference to occur at a specific point, the waves must arrive in phase so their fields reinforce each other. This requirement is met when the spatial path difference between the waves equals an integer multiple of the wavelength, expressed as $\Delta x = n\lambda$.

Step 1: The phenomenon of interference occurs when light waves emitted from coherent sources cross paths. Where the overlapping waves meet, their individual electric field vectors add together according to the superposition principle, redistributing the light intensity into spatial fringes.
Step 2: Constructive interference occurs when the peaks of one wave align with the peaks of another. This reinforcement requires the spatial path difference between the two waves to be an integer multiple of the wavelength: $\Delta x = n\lambda$ (where $n = 0, 1, 2, \ldots$). This phase alignment maximizes the resulting wave amplitude.
Final Answer: Interference is superposition of coherent waves; constructive interference when path difference = nλ

Answer: (See above)

Go Back to Question 29

Q30.

Solution

Concept: Newton's second law of motion states that the net force acting on a constant mass produces a proportional linear acceleration, given by the expression $\vec{F} = m\vec{a}$. When an object experiences a constant force starting from rest ($v_i = 0$), its resulting motion can be analyzed using standard kinematic equations. Its final velocity after a time interval t is given by $v = at$, and its linear displacement over that interval is calculated using the formula $s = \frac{1}{2}at^2$.

Step 1: The problem provides a mass of $m = 3\,\text{kg}$ acted upon by a constant force of $F = 15\,\text{N}$. Using Newton's second law, we find the resulting acceleration: $a = F/m = 15\,\text{N}/3\,\text{kg} = 5\,\text{m}\,\text{s}^{-2}$.
Step 2: Next, we calculate the final linear velocity achieved by the object after accelerating from rest for a duration of $t = 4\,\text{s}$: $v = at = 5\,\text{m}\,\text{s}^{-2} \times 4\,\text{s} = 20\,\text{m}\,\text{s}^{-1}$.
Step 3: Finally, we determine the total linear distance covered during this 4 s interval using the displacement equation: $s = \frac{1}{2}at^2 = \frac{1}{2} \times 5\,\text{m}\,\text{s}^{-2} \times (4\,\text{s})^2 = \frac{1}{2} \times 5 \times 16 = 40\,\text{m}$.
Final Answer: $\text{v} = 20\,\text{m}\,\text{s}^{-1}$, $s = 40\,\text{m}$

Answer: (See above)

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Q31.

Solution

Concept: Ohm's law characterizes steady-state electronic transport through an ideal ohmic conductor, stating that the total structural current density passing through a material is proportional to the local applied electrical force field. This relationship is written as $V = IR$. However, this is not a universal property of all matter, as many physical devices exhibit highly nonlinear responses. Furthermore, the combined equivalent resistance of multiple resistors wired together in a parallel path configuration can be calculated using the reciprocal sum formula: $1/R_{\text{eq}} = \sum 1/R_i$.

Alternative (i): Step 1: Ohm's law asserts that the electrical current flowing through a conductor is directly proportional to the potential difference across its boundary terminals, provided the temperature remains constant. It takes the mathematical form $V = IR$.
Step 2: A primary limitation is its failure in non-ohmic components, such as semiconductor diodes or vacuum tubes, where the current-voltage profile is nonlinear.
Alternative (ii): Step 1: Substituting the given parallel resistors into the reciprocal formula yields: $1/R_{\text{eq}} = 1/2 + 1/4 + 1/8 = 4/8 + 2/8 + 1/8 = 7/8\,\Omega^{-1}$.
Step 2: Inverting this fractional value yields the net equivalent system resistance: $R_{\text{eq}} = 8/7\,\Omega \approx 1.14\,\Omega$.
Final Answer: (i) V = IR; not valid for non-ohmic conductors; (ii) $\text{R}_{\text{eq}} = 8/7\,\Omega$

Answer: (See above)

Go Back to Question 31

Q32.

Solution

Concept: The absolute refractive index of an optical material measures its optical density, defined as the ratio of the speed of light in a vacuum to its phase velocity inside that medium ($n = c/v$). Because light waves slow down upon entering a physical medium, c always exceeds v, ensuring that $n > 1$ for all matter. Total internal reflection occurs when an incident ray fails to cross the boundary into a surrounding medium, reflecting completely back into the host material instead.

Alternative (i): Step 1: The refractive index formula is expressed as $n = c/v$. Because the speed of light in a vacuum is an absolute universal speed limit ($c > v$), the resulting ratio must always be greater than one ($n > 1$).
Alternative (ii): Step 1: Total internal reflection is the complete reflection of a light ray back into its original, optically denser host medium when it strikes an interface at an angle greater than the critical angle.
Step 2: This phenomenon requires two strict physical conditions: (1) Light must travel from a medium of higher refractive index toward one of lower refractive index ($n_1 > n_2$). (2) The angle of incidence must exceed the critical threshold angle: $i > i_c$, defined by $\sin i_c = n_2/n_1$.
Final Answer: (i) n = c/v; (ii) Denser-to-rarer medium and i > i_c

Answer: (See above)

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Q33.

Solution

Concept: When multiple chemical cells are connected in series, their internal electromotive forces and internal resistances combine linearly. The total equivalent voltage of the network is calculated by summing the individual values ($E_{\text{total}} = E_1 + E_2$), and the total internal resistance is the sum of their individual resistances ($r_{\text{total}} = r_1 + r_2$). The steady-state electrical current flowing through the circuit can then be found by applying Ohm's law to the total loop resistance: $I = E_{\text{total}}/(R + r_{\text{total}})$.

Step 1: We are given a circuit with two cells in series ($E_1 = 1.5\,\text{V}$, $r_1 = 0.5\,\Omega$ and $E_2 = 2.0\,\text{V}$, $r_2 = 1.0\,\Omega$). The total equivalent electromotive force is $E = 1.5 + 2.0 = 3.5\,\text{V}$, and the combined internal resistance is $r = 0.5 + 1.0 = 1.5\,\Omega$.
Step 2: The external load resistance is $R = 6.5\,\Omega$. Substituting these values into the loop equation gives the current: $I = 3.5/(1.5 + 6.5) = 3.5/8.0 = 0.4375\,\text{A} \approx 0.44\,\text{A}$.
Step 3: The terminal voltage drop across the external circuit can be calculated using Ohm's law: $V_{\text{ext}} = IR = 0.4375\,\text{A} \times 6.5\,\Omega = 2.84375\,\text{V} \approx 2.84\,\text{V}$.
Final Answer: I $\approx 0.44\,\text{A}$, $V_{\text{ext}} \approx 2.84\,\text{V}$

Answer: (See above)

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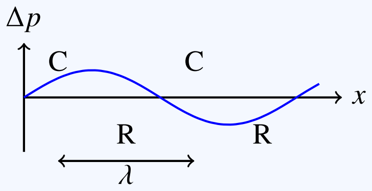
Q34.

Solution

Concept: The propagation of a periodic wave through a continuous medium can be described by the wave speed equation $v = f\lambda$, which links velocity, source frequency, and wavelength. In longitudinal acoustic waves, energy moves forward through alternating regions of high and low pressure. High-pressure regions are called compressions, while low-pressure regions are called rarefactions. The distance between two consecutive compressions or rarefactions equals exactly one wavelength.



Step 1: The problem provides an acoustic wave traveling with a velocity of $v = 340\,\mathrm{m\,s^{-1}}$ at a frequency of $f = 340\,\mathrm{Hz}$. Rearranging the wave equation allows us to isolate the spatial wavelength: $\lambda = v/f = 340/340 = 1.0\,\mathrm{m}$.

Step 2: As the wave propagates, local density oscillations create high-pressure compressions (C) and low-pressure rarefactions (R). These alternating zones are separated by exactly half a wavelength ($\lambda/2 = 0.5\,\mathrm{m}$), forming a periodic spatial pressure pattern.

Final Answer: $\lambda = 1.0\,\mathrm{m}; compressionsandrarefactionsshownabove$

Answer: (See above)

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Q35.

Solution

Concept: Einstein's photoelectric equation uses energy conservation to describe the interactions between individual photons and bound electrons, written as $h\nu = \phi + K_{\max}$. In nuclear physics, fission is a process where a heavy, unstable nucleus splits into lighter, more stable fragments. This transformation releases a significant amount of kinetic and radiative energy because of a net loss in total rest mass.

Alternative (i): Step 1: In the photoelectric equation $h\nu = \phi + K_{\max}$, the term $h\nu$ represents the incoming photon energy, ϕ is the work function of the metal, and $K_{\max}$ is the maximum kinetic energy of the ejected photoelectrons.

Alternative (ii): Step 1: Nuclear fission occurs when a heavy parent nucleus, such as uranium-235, absorbs a thermal neutron. This makes the nucleus unstable, causing it to split into smaller fission products while releasing energy and additional free neutrons.

Step 2: A standard example of this nuclear reaction is expressed as: $^{235}\text{U} + {}^{1}\text{n} \rightarrow {}^{141}\text{Ba} + {}^{92}\text{Kr} + 3\,{}^{1}\text{n} + \text{Energy}$. This reaction is the primary energy source used in commercial nuclear power plants.

Final Answer: (i) h$\nu = \phi + K_{\max}; (ii) U - 235 fission; application : nuclearpower$

Answer: (See above)

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Q36.

Solution

Concept: The surface tension of a liquid creates an inward pressure that increases the internal pressure within any curved fluid interface. For a spherical soap bubble suspended in air, the liquid film forms two distinct concentric surfaces (inner and outer), which doubles the total surface force. The resulting excess pressure is given by $\Delta P = 4\gamma/r$. In contrast, a hollow air bubble submerged inside a pool of water possesses only a single fluid interface, reducing its excess internal pressure expression to $\Delta P = 2\gamma/r$.

Step 1: The system parameters are given as a radius of $r = 2\,\text{cm} = 0.02\,\text{m}$ and a fluid surface tension coefficient of $\gamma = 0.03\,\text{N}\,\text{m}^{-1}$.

Step 2: For the soap bubble, substituting its parameters into the dual-surface equation yields: $\Delta P = 4\gamma/r = (4 \times 0.03)/0.02 = 0.12/0.02 = 6\,\text{Pa}$.

Step 3: For the submerged air bubble, substituting its parameters into the single-surface equation gives: $\Delta P = 2\gamma/r = (2 \times 0.03)/0.02 = 0.06/0.02 = 3\,\text{Pa}$. This shows the soap bubble has twice the excess pressure.

Final Answer: Soap bubble: 6 Pa; Air bubble in water: 3 Pa

Answer: (See above)

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Q37.

Solution

Concept: An isothermal thermodynamic process is a quasi-static transformation during which the internal temperature of a working gas system is held perfectly constant by maintaining continuous thermal contact with an external heat reservoir. The mechanical work performed during an isothermal expansion can be derived by integrating the pressure function ($P = nRT/V$) over the volume change. This integration yields the classical logarithmic equation: $W = nRT\ln(V_2/V_1)$.

Step 1: The problem provides the following parameters: $n = 2$ moles of gas, a constant temperature of $T = 300\,\mathrm{K}$, an initial volume of $V_1 = 2\,\mathrm{L}$, and a final volume of $V_2 = 8\,\mathrm{L}$. The universal gas constant is $R = 8.314\,\mathrm{J\,mol^{-1}\,K^{-1}}$.
Step 2: Substituting these parameters into the work equation gives: $W = 2\times8.314\times300\times\ln(8/2) = 4988.4\times\ln(4)$.
Step 3: Using the logarithmic value $\ln(4)\approx1.3863$, we calculate the total work performed by the gas: $W = 4988.4\times1.3863\approx6915.42\,\mathrm{J}$. Expressing this in kilojoules gives $W\approx6.92\,\mathrm{kJ}$.
Final Answer: W $\approx 6915\,\mathrm{J} or 6.92\,\mathrm{kJ}$

Answer: (See above)

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Q38.

Solution

Concept: Solid-state electronics relies on tailoring semiconductor materials to alter their electrical properties. An extrinsic semiconductor is made by intentionally adding tiny amounts of impurity atoms to an intrinsic crystal lattice to boost its conductivity. A Zener diode is a specialized, heavily doped *p*-*n* junction designed to operate safely in reverse breakdown without failing. Finally, a transistor is a three-terminal semiconductor device that uses a small control current or voltage to modulate a larger current path.

Step 1: Extrinsic semiconductors are doped to control charge carrier concentrations. For example, adding pentavalent phosphorus to silicon yields an *n*-type material with an abundance of free conduction electrons.
Step 2: A Zener diode's heavy doping creates a thin depletion layer that permits sharp Zener breakdown at a specific reverse voltage. This stable voltage reference is widely used for voltage regulation in power supplies.
Step 3: A transistor contains three distinct doped regions: the emitter, base, and collector. This configuration allows it to act as an amplifier or an electronic switch, such as an *n*-*p*-*n* transistor in audio systems.
Final Answer: Extrinsic: doped Si; Zener: voltage regulation; Transistor: amplification/switching

Answer: (See above)

Go Back to Question 38

Q39.

Solution

Concept: The spatial width of the central bright maximum formed in single-slit diffraction is described by the expression $w = 2D\lambda/a$, where D is the screen distance, λ is the wavelength, and a is the slit width. In geometric optics, image formation by a spherical concave mirror follows the mirror equation: $1/v + 1/u = 1/f$. The lateral magnification is given by $m = -v/u$, which determines the final size and orientation of the image.

Alternative (i): Step 1: We are given a slit width of $a = 10^{-4}\,\text{m}$, a screen distance of $D = 2\,\text{m}$, and a wavelength of $\lambda = 5 \times 10^{-7}\,\text{m}$. Substituting these values into the diffraction formula yields: $w = 2 \times 2 \times (5 \times 10^{-7})/10^{-4} = 2 \times 10^{-2}\,\text{m} = 20\,\text{mm}$.
Alternative (ii): Step 1: For a concave mirror with a focal length of $f = -15\,\text{cm}$ and an object distance of $u = -20\,\text{cm}$, we apply the mirror formula: $1/v = 1/f - 1/u = -1/15 - (-1/20) = -1/15 + 1/20 = -1/60$, yielding $v = -60\,\text{cm}$.
Step 2: The negative image distance indicates the image is real and forms 60 cm in front of the mirror. Computing the magnification gives $m = -v/u = -(-60)/(-20) = -3$. The image height is $h_i = |m| \times h_o = 3 \times 3\,\text{cm} = 9\,\text{cm}$, and it is inverted.
Final Answer: (i) w = 20 mm; (ii) v = -60 cm, real, inverted, 9 cm tall

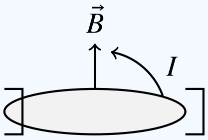
Answer: (See above)

Go Back to Question 39

Q40.

Solution

Concept: The Biot-Savart law determines the total magnetic field generated by a steady current moving through a conductor by integrating the individual magnetic contributions from every current element along the path. For a flat circular coil made of N tightly wound, concentric loops carrying an electrical current I, summing these differential contributions at the center of the coil simplifies the expression to the classical magnetic field formula: $B = \mu_0 NI/(2r)$.



circular coil (100 turns)

Step 1: The Biot-Savart law states that a differential current element $I\,d\vec{l}$ produces an incremental magnetic field given by $d\vec{B} = (\mu_0/4\pi)(I\,d\vec{l} \times \hat{r})/r^2$. At the center, the angle between $d\vec{l}$ and $\hat{r}$ is always 90°.
Step 2: The given parameters are $N = 100$ turns, a current of $I = 0.5$ A, and a radius of $r = 7\,\text{cm} = 0.07\,\text{m}$. Substituting these values into the integrated formula gives: $B = (4\pi \times 10^{-7} \times 100 \times 0.5)/(2 \times 0.07)$.
Step 3: Simplifying the expression yields: $B = (200\pi \times 10^{-7})/0.14 = 1428.57\pi \times 10^{-7} \approx 4.49 \times 10^{-4}\,\text{T}$. This measures the central magnetic field strength.
Final Answer: B $\approx 4.49 \times 10^{-4}$ T

Answer: (See above)

Go Back to Question 40

Q41.

Solution

Concept: Work-energy theorem: net work = ΔK. Momentum conservation in collisions: $m_1v_1 + m_2v_2 = (m_1 + m_2)V$. **Alternative (i): Step 1:** Ball thrown upward: $v = 20\,\text{m}\,\text{s}^{-1}$, at max height $v = 0$. Work by gravity = $-mgh$. **Step 2:** $-mgh = 0 - \frac{1}{2}mv^2$, so $h = v^2/(2g) = 400/20 = 20\,\text{m}$. **Alternative (ii): Step 1:** By momentum conservation: $2000 \times 10 = 3000V$, so $V = 6.67\,\text{m}\,\text{s}^{-1}$. **Step 2:** Initial KE = $\frac{1}{2}(2000)(100) = 100000\,\text{J}$. Final KE = $\frac{1}{2}(3000)(44.44) = 66667\,\text{J}$. KE lost = $33333\,\text{J} \approx 33.3\,\text{kJ}$. **Final Answer:** (i) $h = 20\,\text{m}$; (ii) $V = 6.67\,\text{m}\,\text{s}^{-1}$, KE lost ≈ 33.3 kJ

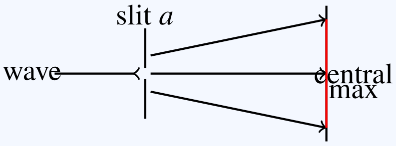
Answer: (See above) **Go Back to Question 41**

Q42.

Solution

Concept: Lens maker's formula relates focal length to refractive index and radii. Photoelectric laws describe emission conditions. Single-slit diffraction minima: $a\sin\theta = n\lambda$. **Alternative (i):**

Step 1 (a): For a thin lens of refractive index μ, refraction at surface 1: $\mu/v_1 - 1/u = (\mu - 1)/R_1$. Refraction at surface 2: $1/v - \mu/v_1 = (1-\mu)/R_2$. Adding and setting $u \to \infty$, $v = f$: $1/f = (\mu - 1)(1/R_1 - 1/R_2)$. **Step 2 (b):** Laws of photoelectric emission: (1) Emission occurs only if $\nu > \nu_0$ (threshold frequency). (2) K_{max} depends on frequency, not intensity. (3) Number of photoelectrons $\propto$ intensity. (4) Emission is instantaneous. **Alternative (ii):**



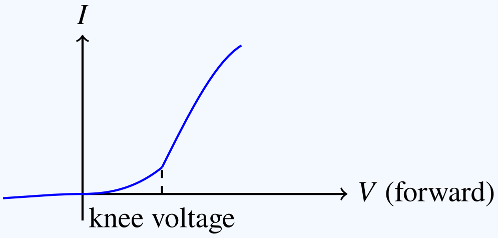
Step 1 (a): Each point on the slit acts as a secondary source. Dividing the slit into two halves, for destructive interference: $(a/2)\sin\theta = \lambda/2$, giving $a\sin\theta = \lambda$. For n-th minimum: $a\sin\theta = n\lambda$. **Step 2 (b):** $\Delta m = 2(1.00728) + 2(1.00867) - 4.00260 = 0.02930\,\text{u}$. **Step 3 (b):** Binding energy $= 0.02930 \times 931.5 = 27.29\,\text{MeV}$. Per nucleon $= 27.29/4 = 6.82\,\text{MeV}$. **Final Answer:** (i)(a) $1/f = (\mu - 1)(1/R_1 - 1/R_2)$; (b) threshold frequency, KE $\propto$ frequency; (ii)(a) $a\sin\theta = n\lambda$; (b) 6.82 MeV/nucleon

Answer: (See above) **Go Back to Question 42**

Q43.

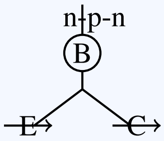
Solution

Concept: Momentum conservation in inelastic collision. First law of thermodynamics: $\Delta U = Q - W$. Doppler effect: apparent frequency change due to relative motion. Diode V-I characteristics. **Alternative (i): Step 1 (a):** Momentum conservation: $0.01 \times 400 + 0.99 \times 0 = (0.01 + 0.99)V$, so $V = 4\,\mathrm{m\,s^{-1}}$. **Step 2 (b):** First law: $\Delta U = Q - W$. Example: Gas heated at constant volume absorbs heat Q; since $W = 0$, $\Delta U = Q$. **Step 3 (c):** Doppler effect: apparent change in frequency due to relative motion between source and observer. Application: radar speed guns. **Step 4 (d):**



The V-I curve shows negligible current until knee voltage, then rapid rise.

Alternative (ii): Step 1 (a): Power $= mgh/t = 500 \times 10 \times 20/25 = 4000\,\mathrm{W} = 4\,\mathrm{kW}$. **Step 2 (b):** Kelvin–Planck: No heat engine operating in a cycle can convert all absorbed heat into work without rejecting some heat to a cold reservoir. **Step 3 (c):** Transverse: particles vibrate ⊥ to wave direction (e.g., light). Longitudinal: particles vibrate || to wave direction (e.g., sound in air). **Step 4 (d):**



Final Answer: (i)(a) $4\,\mathrm{m\,s^{-1}}$; (b) $\Delta U = Q - W$; (c) frequency change from relative motion; (d) V-I curve shown; (ii)(a) 4 kW; (b) no 100% efficient heat engine; (c) Transverse: light; Longitudinal: sound; (d) n-p-n symbol drawn

Answer: (See above) **Go Back to Question 43**

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	B	4	A	5	C
6	C	7	B	8	C	9	B	10	B
11	A	12	A	13	B	14	B	15	C
16	A								