NEET-UG Physics Sample Paper-15

Duration: 1 Hour **Maximum Marks: 180**

Instructions

- This paper contains a total of 45 Multiple Choice Questions.
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Q1. Two moles of ideal helium gas are in a rubber balloon at 30°C. The balloon is fully expandable and can be assumed to require no energy in its expansion. The temperature of the gas in the balloon is slowly changed to 35°C. The amount of heat required in raising the temperature is nearly: (take $R = 8.31$ J/mol·K)

(A) 62 J

(B) 104 J

(C) 124 J

(D) 208 J

Q2. Which type of electron emission requires a strong electric field to accelerate electrons to overcome potential barriers?

(A) Photoelectric emission

(B) Thermionic emission

(C) Field emission

(D) Secondary emission

Q3. A nucleus of mass M emits a photon of frequency ν and the nucleus recoils. The recoil energy will be:

(A) $Mc^2 - h\nu$

(B) $h^2\nu^2/2Mc^2$

(C) 0

(D) $h\nu$

Q4. A monoatomic gas ($\gamma = 5/3$) at pressure p is suddenly compressed to $1/64$th of its volume adiabatically. Then, the pressure of the gas is:

(A) $8p$

(B) $42/3p$

(C) $256p$

(D) $1024p$

Q5. 5 moles of neon gas at 2 atm and 27°C is adiabatically compressed to $1/3^{\text{rd}}$ of its initial volume. $[\gamma = 1.67, C_v = 0.148$ cal/g, $M = 20.18$ g/mole$]$. Then, which of the following statement is true?

(A) Pressure will change to 6 atm

(B) Temperature will become less than 600 K

(C) Work done by the gas is non-zero

(D) Work done on the gas is non-zero

Q6. A sample of perfect gas is compressed isothermally to half its volume. If it is compressed adiabatically to the same volume, the final pressure of the gas will be:

(A) more

(B) less

(C) same

(D) more or less depending on the initial temperature of the gas

Q7. Match the following physical processes with the appropriate type of thermodynamic process: (A) X-rays emission by metal target (B) H_2 and O_2 explosion in rigid container (C) Diesel engine slug compression (D) Visible breath in winter (E) Water vapor condensation slowly.

(A) A-4, B-5, C-2, D-1, E-3

(B) A-3, B-4, C-1, D-2, E-5

(C) A-5, B-3, C-2, D-1, E-4

(D) A-2, B-5, C-3, D-4, E-1

Q8. 5 moles of hydrogen ($\gamma = 7/5$) initially at 0°C are compressed adiabatically so that the temperature becomes 400°C. The increase in internal energy in kJ is: ($R = 8.30$ J/mol K)

(A) 21.55 kJ

(B) 41.50 kJ

(C) 65.55 kJ

(D) 80.55 kJ

Q9. A tennis ball (m_2) sits on a basketball (m_1). They are dropped from height h. If all collisions are elastic and $m_1 \gg m_2$, to what approximate height does the tennis ball bounce?

(A) $d + h$

(B) $d + 2h$

(C) $d + 3h$

(D) $d + 9h$

Q10. An electron of mass m and charge e initially at rest is accelerated by constant electric field E. The rate of change of de-Broglie wavelength at time t is:

(A) $-h/eEt^2$

(B) $-eht/E$

(C) $-mh/eEt^2$

(D) $-h/eE$

Q11. Dielectric constant of ordinary water is ______ than heavy water.

(A) More

(B) Less

(C) Equal

(D) Cannot be predicted

Q12. Three moles of an ideal gas expanded spontaneously into the vacuum. The work done will be:

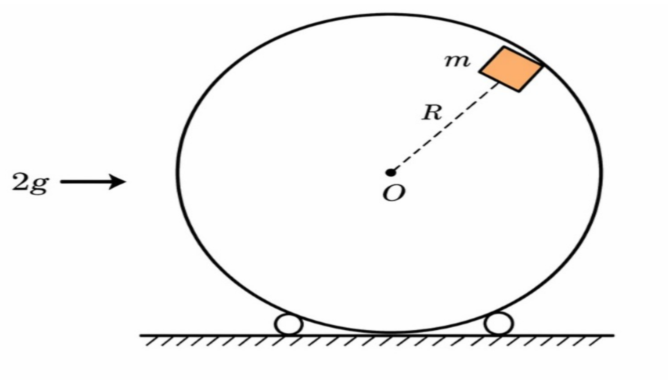
(A) Infinite

(B) 3 Joules

(C) 9 Joules

(D) Zero

Q13. A block of mass m is inside a smooth hollow cylinder of radius R. The cylinder is given constant horizontal acceleration $2g$. The maximum angular displacement of the block is:



(A) $2\tan^{-1} 2$

(B) $\tan^{-1} 2$

(C) $\tan^{-1} 1$

(D) $\tan^{-1} 0.5$

Q14. Adiabatic compressibility of an ideal gas at a pressure P is:

(A) γP

(B) γ / P

(C) $1/\gamma P$

(D) None of these

Q15. A constant pressure P is applied on all sides of a sphere. By what amount should the temperature be raised to maintain original volume? (Expansion coeff α, compressibility σ)

(A) $\sigma P/\alpha$

(B) $\alpha P/\sigma$

(C) $\alpha\sigma P$

(D) $P/\alpha\sigma$

Q16. A monatomic gas ($\gamma = 5/3$) is suddenly compressed to $1/8^{\text{th}}$ of its initial volume adiabatically. If the initial pressure is P, the final pressure of the gas will be:

(A) $24/5P$

(B) $8P$

(C) $32P$

(D) $40/3P$

Q17. For the following transitions in hydrogen-like atoms, select the **correct** relation between frequencies (ν) and wavelengths (λ): Transition 'c' is from $n = 3$ to $n = 1$, transition 'a' is from $n = 3$ to $n = 2$, and transition 'b' is from $n = 2$ to $n = 1$.

(A) $\nu_c = \nu_a + \nu_b$ and $\lambda_c = \frac{\lambda_a \lambda_b}{\lambda_a + \lambda_b}$

(B) $\nu_c = \nu_a + \nu_b$ and $\lambda_c = \lambda_a + \lambda_b$

(C) $\nu_c = \frac{\nu_a \nu_b}{\nu_a + \nu_b}$ and $\lambda_c = \lambda_a + \lambda_b$

(D) $\nu_c = \sqrt{\nu_a^2 + \nu_b^2}$ and $\lambda_c = \sqrt{\lambda_a^2 + \lambda_b^2}$

Q18. On observing light from three stars P, Q, and R, the maximum intensity is found in the violet, red, and green regions respectively. If T_P, T_Q, T_R are their absolute temperatures, then:

(A) $T_P < T_R < T_Q$

(B) $T_P < T_Q < T_R$

(C) $T_P > T_Q > T_R$

(D) $T_P > T_R > T_Q$

Q19. If a source of power 4 kW produces 10^{20} photons/second, to which part of the electromagnetic spectrum does the radiation belong?

(A) Microwaves

(B) γ-rays

(C) X-rays

(D) Ultraviolet rays

Q20. n elastic balls are placed in a line on a smooth track. Their masses are $m, m/2, m/2^2, \ldots, m/2^{n-1}$. What is the minimum speed u given to the first ball so the n^{th} ball just completes a vertical circle of radius r?

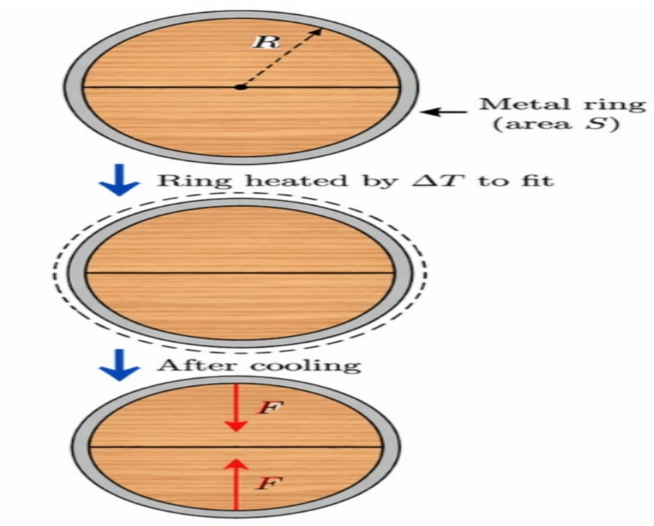
(A) $(3/4)^{n-1}\sqrt{5gr}$

(B) $(4/3)^{n-1}\sqrt{5gr}$

(C) $(3/2)^{n-1}\sqrt{5gr}$

(D) $(2/3)^{n-1}\sqrt{5gr}$

Q21. A wooden wheel of radius R is made of two semicircular parts held by a metal ring of area S. The ring is heated by ΔT to fit and then cooled. Find the force with which one half presses the other. (Young's modulus Y, expansion coeff α)



(A) $SY\alpha\Delta T$

(B) $2SY\alpha\Delta T$

(C) $\pi SY\alpha\Delta T$

(D) $2\pi SY\alpha\Delta T$

Q22. A gas is heated isobarically and the heat used for external work is W. Find the total amount of heat supplied (Q) in terms of W and γ.

(A) $W\gamma/(\gamma-1)$

(B) $W(\gamma-1)/\gamma$

(C) $W\gamma$

(D) $W/(\gamma-1)$

Q23. The de-Broglie wavelength of a neutron (mass m) in thermal equilibrium with heavy water at temperature T (Kelvin) is:

(A) $h/\sqrt{mkT}$

(B) $h/\sqrt{3mkT}$

(C) $2h/\sqrt{3mkT}$

(D) $2h/\sqrt{mkT}$

Q24. The angular speed of a wheel increases from 360 rpm to 1200 rpm in 14 seconds. Its angular acceleration is:

(A) 2π rad/s^2

(B) 28π rad/s^2

(C) 120π rad/s^2

(D) 1 rad/s^2

Q25. The dimension of stress is:

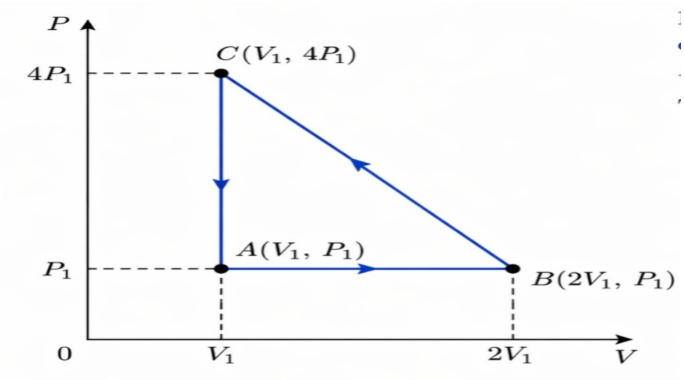
(A) $[MLT^{-2}]$

(B) $[ML^2T^{-2}]$

(C) $[ML^{-1}T^{-2}]$

(D) $[ML^0T^{-2}]$

Q26. An ideal gas is taken via a triangular path $ABCA$ on a $P-V$ diagram. $A(V_1, P_1)$, $B(2V_1, P_1)$, and $C(V_1, 4P_1)$. If the path is anticlockwise, the net work done is:



(A) $3P_1V_1$

(B) $-3P_1V_1$

(C) $-1.5P_1V_1$

(D) $1.5P_1V_1$

Q27. An unmanned space probe is thrown so it does not return to Earth. Its velocity v must satisfy:

(A) $v = \sqrt{2GM/R}$

(B) $v > \sqrt{2GM/R}$

(C) $v \geq \sqrt{2GM/R}$

(D) $v < \sqrt{2GM/R}$

Q28. Which of the following metals are ferromagnetic?

(A) Co, Mn, Ni

(B) Fe, Co, Ni

(C) Cu, Au, Fe

(D) Cu, Pt, Co

Q29. An EM wave (λ) is incident on a surface with negligible work function. If the emitted photoelectron (mass m) has de-Broglie wavelength λ_d, then:

(A) $\lambda = (2mc/h)\lambda_d^2$

(B) $\lambda_d = (2mc/h)\lambda^2$

(C) $\lambda = (h/2mc)\lambda_d^2$

(D) $\lambda = (2m/hc)\lambda_d^2$

Q30. An electron (mass m) and a photon have the same energy E. The ratio of their de-Broglie wavelengths (λ_e/λ_p) is:

(A) $\frac{1}{c}\sqrt{E/2m}$

(B) $\sqrt{E/2m}$

(C) $c\sqrt{2mE}$

(D) $\frac{1}{c}\sqrt{2m/E}$

Q31. A transformer has an efficiency of 90% and is working on 200 V and 3 kW power supply. If the current in the secondary coil is 6 A, then the voltage across the secondary coil is:

(A) 300 V

(B) 450 V

(C) 500 V

(D) 600 V

Q32. The half-life of a radioactive substance is 20 minutes. The time taken between 20% and 80% decay will be:

(A) 20 min

(B) 40 min

(C) 30 min

(D) 25 min

Q33. A convex lens of focal length f is placed in contact with a concave lens of focal length f. The equivalent focal length of the combination is:

(A) $f/2$

(B) f

(C) 0

(D) Infinite

Q34. Which of the following has the highest penetrating power?

(A) α-rays

(B) β-rays

(C) γ-rays

(D) X-rays

Q35. A particle is moving in a circle of radius r with a constant speed v. The change in velocity after rotating through an angle θ is:

(A) $2v\sin(\theta/2)$

(B) $2v\cos(\theta/2)$

(C) $v\sin\theta$

(D) $v(1-\cos\theta)$

Q36. The electric field at a distance r from an infinitely long straight wire of linear charge density λ is:

(A) $\lambda/2\pi\epsilon_0 r$

(B) $\lambda/4\pi\epsilon_0 r$

(C) $\lambda/2\pi\epsilon_0 r^2$

(D) $\lambda^2/2\pi\epsilon_0 r$

Q37. In a Young's Double Slit Experiment, the fringe width is β. If the entire apparatus is immersed in a liquid of refractive index μ, the new fringe width will be:

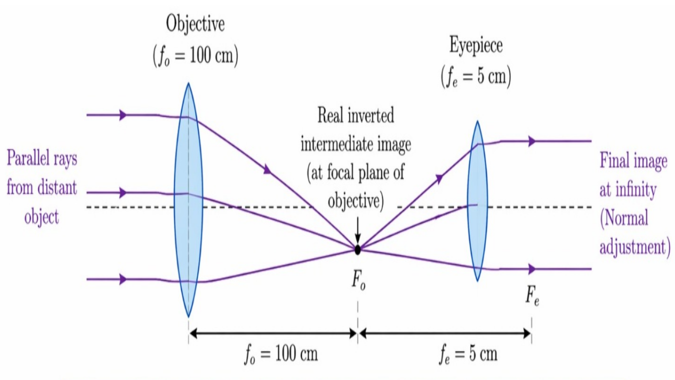
(A) β

(B) $\mu\beta$

(C) β/μ

(D) $\beta/(\mu - 1)$

Q38. An astronomical telescope has an objective of focal length 100 cm and an eyepiece of focal length 5 cm. The magnifying power for normal adjustment is:



(A) 20

(B) 105

(C) 95

(D) 500

Q39. The resistance of a wire is R. If it is melted and stretched to n times its original length, its new resistance will be:

(A) nR

(B) R/n

(C) n^2R

(D) R/n^2

Q40. The magnetic field at the center of a circular current-carrying loop of radius R and current I is:

(A) $\mu_0 I/2R$

(B) $\mu_0 I/4R$

(C) $\mu_0 I/2\pi R$

(D) $\mu_0 I/4\pi R$

Q41. If the energy of a photon is tripled, its momentum will:

(A) Become 3 times

(B) Become 9 times

(C) Become $\sqrt{3}$ times

(D) Remain the same

Q42. A wire of length L and resistance R is bent into a circle. The resistance between any two diametrically opposite points is:

(A) R

(B) $R/2$

(C) $R/4$

(D) $R/8$

Q43. The work function of a metal is 4.2 eV. If the stopping potential is 3 V, the energy of the incident photon is:

(A) 1.2 eV

(B) 7.2 eV

(C) 4.2 eV

(D) 3 eV

Q44. In a p-type semiconductor, the majority charge carriers are:

(A) Electrons

(B) Holes

(C) Neutrons

(D) Protons

Q45. The binding energy per nucleon is maximum for which nucleus?

(A) ^{4}He

(B) ^{56}Fe

(C) ^{238}U

(D) ^{2}H

Detailed Solutions

Q1.

Solution

Concept: Since the balloon is "fully expandable" and offers no resistance, the process of heating the gas happens at constant pressure (isobaric process). The heat required is calculated using the molar specific heat capacity at constant pressure (C_P). For a monatomic gas like Helium, $C_P = \frac{5}{2}R$.**Solution:**Use the formula for heat at constant pressure: $Q = nC_P\Delta T$.Given values: $n = 2$, $\Delta T = 35 - 30 = 5$ K, $R = 8.31$ J/mol · K.Calculate C_P for Helium:

$$C_P = \frac{5}{2} \times 8.31 = 20.775 \text{ J/mol} \cdot \text{K}$$

Calculate total heat Q:

$$Q = 2 \times 20.775 \times 5 = 10 \times 20.775 = 207.75 \text{ J}$$

Rounding to the nearest value provided in the options gives 208 J.**Final Answer:**208 J

Answer: (D)

Q2.

Solution

Concept:
Electron emission is the process by which electrons are ejected from the surface of a material (usually a metal). Different methods provide the necessary energy to overcome the "work function" barrier. - **Thermionic:** Uses thermal energy (heat). - **Photoelectric:** Uses light (photons). - **Secondary:** Uses impact from primary electrons. - **Field Emission:** Uses a very strong external electric field.
Solution:
1. In Field Emission (also known as Cold Cathode Emission), a very high electric field (typically 10^8 V/m) is applied to the metal surface. 2. This strong electric field creates a large potential gradient at the surface, effectively "pulling" the electrons out of the metal. 3. This process does not require high temperatures or light, but rather relies on the strength of the field to allow electrons to tunnel through or overcome the surface potential barrier.
Final Answer: Field emission requires a strong electric field to accelerate electrons.

Answer: (C)

Q3.

Solution

Concept:
When a nucleus at rest emits a photon, it must recoil in the opposite direction to conserve momentum. The momentum of a photon is given by $p_p = \frac{h\nu}{c}$. By the principle of conservation of momentum, the magnitude of the nucleus's recoil momentum (p_n) must be equal to the photon's momentum.

Solution:
1. Conservation of linear momentum gives:

$$p_{nucleus} = p_{photon} = \frac{h\nu}{c}$$

2. The kinetic energy of the recoiling nucleus (K) can be expressed in terms of its momentum and mass M:

$$K = \frac{p_{nucleus}^2}{2M}$$

3. Substitute the value of $p_{nucleus}$:

$$K = \frac{(h\nu/c)^2}{2M}$$

4. Simplify the expression:

$$K = \frac{h^2\nu^2}{2Mc^2}$$

Final Answer: The recoil energy will be $h^2\nu^2/2Mc^2$.

Answer: (B)

Q4.

Solution

Concept:
In an adiabatic process, there is no heat exchange with the surroundings ($Q = 0$). The relationship between pressure (P) and volume (V) for an ideal gas undergoing an adiabatic change is given by the Poisson's equation:

$$PV^{\gamma} = \text{constant}$$

where γ is the adiabatic index (ratio of specific heats).

Solution:
1. Let initial state be (P, V) and final state be $(P', V/64)$. 2. Apply the adiabatic relation:

$$PV^{\gamma} = P'(V/64)^{\gamma}$$

3. Solve for P':

$$P' = P\left(\frac{V}{V/64}\right)^{\gamma} = P(64)^{\gamma}$$

4. Substitute $\gamma = 5/3$ for a monoatomic gas:

$$P' = P(64)^{5/3}$$

5. Calculate $(64)^{1/3}$ first, which is 4 (since $4^3 = 64$):

$$P' = P(4)^5$$

6. Calculate $4^5 = 1024$:

$$P' = 1024p$$

Final Answer: The new pressure is $1024p$.

Answer: (D)

Q5.

Solution

Concept:
For an adiabatic process, PV^{γ} = constant and $TV^{\gamma-1}$ = constant. Work is done during compression. By the first law of thermodynamics ($\Delta Q = \Delta U + W$), since $\Delta Q = 0$ in an adiabatic process, we have $W = -\Delta U$.

Solution:
1. **Pressure check:** $P_2 = P_1(V_1/V_2)^{\gamma} = 2(3)^{1.67}$. Since $3^{1.67}$ is significantly greater than 3, P_2 will be much higher than 6 atm. Statement A is false. 2. **Temperature check:** $T_2 = T_1(V_1/V_2)^{\gamma-1}$. Given $T_1 = 27 + 273 = 300$ K, and $V_1/V_2 = 3$:

$$T_2 = 300(3)^{0.67}$$

Since $3^{0.67} > 2$, T_2 will be greater than 600 K. Statement B is false. 3. **Work done:** In any compression process (adiabatic or otherwise), the volume changes ($\Delta V \neq 0$).

$$W = \int P dV$$

Since the gas is compressed, work is done *on* the gas. In adiabatic processes, $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$. This value is non-zero. 4. Statement D is the most fundamentally correct description of the physics here: work is performed on the system to increase its internal energy.

Final Answer: Work done on the gas is non-zero.

Answer: (D)

Q6.

Solution

Concept:
The relationship between pressure (P) and volume (V) depends on the type of thermodynamic process. For an isothermal process (constant temperature), the relation is PV = constant. For an adiabatic process (no heat exchange), the relation is PV^γ = constant, where γ (the adiabatic index) is always greater than 1 for any gas.

Solution:
1. Let the initial pressure be P_0 and initial volume be V_0. 2. In the **Isothermal** case, the final volume is $V = V_0/2$. The final pressure P_{iso} is:

$$P_{iso} = P_0\left(\frac{V_0}{V}\right) = P_0(2) = 2P_0$$

3. In the **Adiabatic** case, for the same final volume $V = V_0/2$, the final pressure P_{adia} is:

$$P_{adia} = P_0\left(\frac{V_0}{V}\right)^\gamma = P_0(2)^\gamma$$

4. Since $\gamma > 1$, it follows that $2^\gamma > 2$. 5. Therefore, $P_{adia} > P_{iso}$. 6. Physically, this happens because in adiabatic compression, the temperature also rises, further increasing the pressure beyond just the effect of volume reduction.

Final Answer: The final pressure will be more.

Answer: (A)

Q7.

Solution

Concept:
Thermodynamic processes are classified based on which state variables (P, V, T) remain constant or the nature of energy exchange. - **Isochoric:** Constant volume. - **Adiabatic:** Rapid process with no heat exchange. - **Isothermal:** Very slow process with constant temperature. - **Non-equilibrium:** Rapid, chaotic transitions where state variables are not uniform.

Solution:
1. **(A) X-rays emission:** When high-speed electrons hit a target, the energy transition is sudden and chaotic, characterizing a **Non-equilibrium process (4)**. 2. **(B) Explosion in a rigid container:** A "rigid container" implies that the volume cannot change. Thus, it is an **Isochoric process (5)**. 3. **(C) Diesel engine compression:** The compression of the fuel-air mixture in a cylinder happens so rapidly that there is no time for heat exchange, making it an **Adiabatic process (2)**. 4. **(D) Visible breath:** Exhaling against atmospheric pressure is essentially an **Isobaric process (1)**. 5. **(E) Slow condensation:** Phase changes occurring "very slowly" allow for constant temperature, which is an **Isothermal process (3)**.

Final Answer: The correct matching is A-4, B-5, C-2, D-1, E-3.

Answer: (A)

Q8.

Solution

Concept:

Internal energy (U) of an ideal gas depends only on its temperature. The change in internal energy (ΔU) for n moles of a gas is given by:

$$\Delta U = nC_v\Delta T$$

where $C_v = \frac{R}{\gamma-1}$ is the molar heat capacity at constant volume.

Solution:

1. Identify the given values: $n = 5$ moles, $\gamma = 7/5$, $R = 8.30$ J/mol K. 2. Initial temperature $T_1 = 0°\text{C} = 273$ K. 3. Final temperature $T_2 = 400°\text{C} = 673$ K. 4. Temperature change $\Delta T = T_2 - T_1 = 400$ K. 5. Calculate C_v:

$$C_v = \frac{R}{7/5 - 1} = \frac{R}{2/5} = \frac{5R}{2}$$

6. Substitute into the ΔU formula:

$$\Delta U = 5 \times \left(\frac{5 \times 8.30}{2}\right) \times 400$$

7. Simplify the calculation:

$$\Delta U = 25 \times 8.30 \times 200 = 5000 \times 8.30$$

$$\Delta U = 41,500 \text{ J}$$

8. Convert to kilojoules:

$$\Delta U = 41.50 \text{ kJ}$$

Final Answer: The increase in internal energy is 41.50 kJ.

Answer: (B)

Q9.

Solution

Concept:
This is a classic "Super-ball" collision problem. When two balls are dropped together, the heavier ball (m_1) hits the ground first and reverses its velocity. It then strikes the lighter ball (m_2) which is still moving downwards. We use the relative velocity approach for elastic collisions where $m_1 \gg m_2$.

Solution:
1. Just before hitting the ground, both balls have velocity $v = \sqrt{2gh}$ downwards. 2. The basketball (m_1) hits the ground and, due to the elastic collision, reverses its velocity to v upwards. 3. Now, the tennis ball (m_2) is moving down with v, and the basketball is moving up with v. 4. In the frame of the basketball (which is much heavier and acts like a moving floor), the tennis ball is approaching at a relative speed of $v + v = 2v$. 5. After the elastic collision, the tennis ball must recede from the basketball at the same relative speed, $2v$, upwards relative to the basketball. 6. Velocity of tennis ball in ground frame = (Velocity relative to basketball) + (Velocity of basketball)

$$V_{final} = 2v \text{ (up)} + v \text{ (up)} = 3v$$

7. The height H reached is proportional to the square of the velocity:

$$H = \frac{(3v)^2}{2g} = 9\left(\frac{v^2}{2g}\right) = 9h$$

8. Including the initial separation d, the total height from the ground is $d + 9h$.
Final Answer: The tennis ball bounces to a height of $d + 9h$.

Answer: (D)

Q10.

Solution

Concept:

The de-Broglie wavelength (λ) is given by $\lambda = \frac{h}{p}$, where p is the momentum. In a constant electric field E, an electron experiences a constant force $F = eE$. The momentum at any time t (starting from rest) is given by $p = Ft = eEt$.

Solution:

1. Express the wavelength as a function of time:

$$\lambda(t) = \frac{h}{eEt} = \left(\frac{h}{eE}\right)t^{-1}$$

2. To find the rate of change, differentiate λ with respect to time t:

$$\frac{d\lambda}{dt} = \frac{d}{dt}\left[\left(\frac{h}{eE}\right)t^{-1}\right]$$

3. Apply the power rule for differentiation ($\frac{d}{dt}t^n = nt^{n-1}$):

$$\frac{d\lambda}{dt} = \left(\frac{h}{eE}\right)(-1)t^{-2}$$

4. Simplify the expression:

$$\frac{d\lambda}{dt} = -\frac{h}{eEt^2}$$

Final Answer: The rate of change of the de-Broglie wavelength is $-h/eEt^2$.

Answer: (A)

Q11.

Solution

Concept:

The dielectric constant (ϵ_r) of a substance measures its ability to store electrical potential energy under the influence of an electric field. It is heavily influenced by the polarity and the molecular weight of the molecules. Ordinary water (H_2O) and heavy water (D_2O) have very similar chemical structures, but the deuterium atom in heavy water is twice as heavy as the hydrogen atom.

Solution:

1. At room temperature (25°C), the dielectric constant of ordinary water is approximately 78.4. 2. For heavy water (D_2O), the dielectric constant is slightly lower, approximately 78.06. 3. This difference arises because the $D - O - D$ bond in heavy water is slightly stronger and less polarizable than the $H - O - H$ bond due to the greater mass of deuterium, which affects the dipole-dipole interactions and the response to an external electric field. 4. Therefore, the dielectric constant of ordinary water is higher (more) than that of heavy water.

Final Answer: Dielectric constant of ordinary water is more than heavy water.

Answer: (A)

Q12.

Solution

Concept:

Work done (W) by a gas during expansion is defined as the integral of external pressure (P_{ext}) over the change in volume (ΔV):

$$W = \int P_{ext} dV$$

In a "spontaneous expansion into a vacuum" (also known as free expansion), the gas expands into a region where there is no resisting pressure.

Solution:

1. By definition, a vacuum is a space that is empty of matter and exerts no pressure. 2. Therefore, the external pressure $P_{ext} = 0$. 3. Substituting this into the work formula:

$$W = \int (0) dV = 0$$

4. Even though the volume of the 3 moles of gas increases significantly, since there is no opposing force to overcome, the work done by the system is zero.

Final Answer: The work done will be Zero.

Answer: (D)

Q13.

Solution

Concept:

When the cylinder accelerates horizontally at $a = 2g$, a block inside experiences a pseudo-force $F_p = ma$ in the opposite direction. To find the maximum angular displacement, we use the Work-Energy Theorem. The block will reach its maximum height when its kinetic energy (relative to the cylinder) becomes zero.

Solution:

1. In the frame of the cylinder, two forces do work: Gravity (mg) downwards and the Pseudo-force ($m \cdot 2g$) horizontally. 2. Let the block move to an angle θ from the vertical. 3. Work done by gravity: $W_g = -mgR(1 - \cos\theta)$. 4. Work done by pseudo-force: $W_p = m(2g)R\sin\theta$. 5. By Work-Energy Theorem ($\Delta K = W_{net}$):

$$0 = 2mgR\sin\theta - mgR(1 - \cos\theta)$$

6. Divide by mgR:

$$2\sin\theta = 1 - \cos\theta$$

7. Use trigonometric identities $\sin\theta = 2\sin(\theta/2)\cos(\theta/2)$ and $1 - \cos\theta = 2\sin^2(\theta/2)$:

$$2(2\sin(\theta/2)\cos(\theta/2)) = 2\sin^2(\theta/2)$$

$$2\cos(\theta/2) = \sin(\theta/2)$$

$$\tan(\theta/2) = 2$$

8. Therefore, $\theta/2 = \tan^{-1} 2$, which means $\theta = 2\tan^{-1} 2$.

Final Answer: The maximum angular displacement is $2\tan^{-1} 2$.

Answer: (A)

Q14.

Solution

Concept:

Compressibility (β) is the reciprocal of the Bulk Modulus (B).

$$\beta = \frac{1}{B}$$

The Bulk Modulus is defined as $B = -V\frac{dP}{dV}$. For an adiabatic process, the relationship is PV^γ = constant.

Solution:

1. Differentiating $PV^\gamma = C$ with respect to V:

$$V^\gamma \frac{dP}{dV} + P(\gamma V^{\gamma-1}) = 0$$

2. Rearranging to find the adiabatic bulk modulus (B_{ad}):

$$V^\gamma \frac{dP}{dV} = -\gamma P V^{\gamma-1}$$

$$\frac{dP}{dV} = -\frac{\gamma P}{V}$$

$$B_{ad} = -V\left(-\frac{\gamma P}{V}\right) = \gamma P$$

3. The adiabatic compressibility is the inverse of this:

$$\beta_{ad} = \frac{1}{B_{ad}} = \frac{1}{\gamma P}$$

Final Answer: Adiabatic compressibility is $1/\gamma P$.

Answer: (C)

Q15.

Solution

Concept:
The volume of a substance changes due to both pressure and temperature. For the volume to remain constant, the decrease in volume caused by the applied pressure must be exactly balanced by the increase in volume caused by thermal expansion.

Solution:
1. The change in volume due to pressure is given by compressibility (σ):

$$\Delta V_p = -\sigma V P$$

2. The change in volume due to temperature increase (ΔT) is given by the coefficient of volume expansion (α):

$$\Delta V_T = \alpha V \Delta T$$

3. For the net change in volume to be zero:

$$\Delta V_T + \Delta V_p = 0$$

$$\alpha V \Delta T = \sigma V P$$

4. Solving for ΔT:

$$\Delta T = \frac{\sigma P}{\alpha}$$

Final Answer: The temperature should be raised by $\sigma P/\alpha$.

Answer: (A)

Q16.

Solution

Concept: For an adiabatic process, PV^γ = constant. For a monatomic gas, the adiabatic index $\gamma = 5/3$.
Solution: 1. Relation: $P_1 V_1^\gamma = P_2 V_2^\gamma$ 2. Given $V_2 = V_1/8$:

$$P_2 = P_1 \left(\frac{V_1}{V_1/8}\right)^{5/3} = P(8)^{5/3}$$

3. $8^{5/3} = (8^{1/3})^5 = 2^5 = 32$. 4. $P_2 = 32P$.
Final Answer: The final pressure is $32P$.

Answer: (C)

Q17.

Solution

Concept: In a hydrogen-like atom, the energy levels are quantized. When an electron undergoes a transition from a higher energy state to a lower one, it emits a photon with energy E corresponding to the difference between these levels. According to the principle of conservation of energy, if a large transition (like $n = 3$ to $n = 1$) is broken into intermediate steps (like $n = 3$ to $n = 2$ and $n = 2$ to $n = 1$), the total energy of the large transition is equal to the sum of the energies of the individual steps.

Solution: 1. Let the energy of the transitions be E_c $(3 \to 1)$, E_a $(3 \to 2)$, and E_b $(2 \to 1)$. 2. Based on the energy level diagram:

$$E_c = E_a + E_b$$

3. **For Frequencies (ν):** Using the relation $E = h\nu$:

$$h\nu_c = h\nu_a + h\nu_b \implies \nu_c = \nu_a + \nu_b$$

4. **For Wavelengths (λ):** Using the relation $E = \frac{hc}{\lambda}$:

$$\frac{hc}{\lambda_c} = \frac{hc}{\lambda_a} + \frac{hc}{\lambda_b}$$

$$\frac{1}{\lambda_c} = \frac{1}{\lambda_a} + \frac{1}{\lambda_b} = \frac{\lambda_a + \lambda_b}{\lambda_a \lambda_b}$$

5. Taking the reciprocal to find λ_c:

$$\lambda_c = \frac{\lambda_a \lambda_b}{\lambda_a + \lambda_b}$$

Final Answer: $\nu_c = \nu_a + \nu_b$ and $\lambda_c = \frac{\lambda_a \lambda_b}{\lambda_a + \lambda_b}$

Answer: (A)

Q18.

Solution

Concept: Wien's Displacement Law relates the temperature of a blackbody to the wavelength at which it emits the maximum intensity of radiation. The law is expressed as:

$$\lambda_{max}T = b$$

where b is Wien's constant (2.898×10^{-3} m·K). This implies that the absolute temperature T is inversely proportional to the peak wavelength λ_{max} ($T \propto 1/\lambda_{max}$).

Solution: 1. Identify the wavelengths of the given colors in the visible spectrum (VIBGYOR). The order of increasing wavelength is:

$$\lambda_{violet} < \lambda_{indigo} < \lambda_{blue} < \lambda_{green} < \lambda_{yellow} < \lambda_{orange} < \lambda_{red}$$

2. From the problem: * Star P (Violet): λ_P is the smallest. * Star R (Green): λ_R is intermediate. * Star Q (Red): λ_Q is the largest. 3. Since $T \propto 1/\lambda_{max}$, the star with the shortest wavelength has the highest temperature:

$$T_P > T_R > T_Q$$

Final Answer: $T_P > T_R > T_Q$

Answer: (D)

Q19.

Solution

Concept: The total power P of a source is the energy emitted per unit time. If a source emits n photons per second, each with energy $E = hc/\lambda$, then the power is given by:

$$P = n \times \frac{hc}{\lambda}$$

where h is Planck's constant (6.63×10^{-34} J·s) and c is the speed of light (3×10^8 m/s).
Solution: 1. Given: $P = 4$ kW $= 4000$ W, $n = 10^{20}$ photons/s. 2. Rearrange the formula to solve for wavelength λ:

$$\lambda = \frac{n \cdot h \cdot c}{P}$$

3. Substitute the values:

$$\lambda = \frac{10^{20} \times (6.63 \times 10^{-34}) \times (3 \times 10^8)}{4000}$$

$$\lambda = \frac{19.89 \times 10^{-6}}{4000} \approx 4.97 \times 10^{-9} \text{ m}$$

4. $\lambda \approx 5$ nm $= 50$ Å. 5. Electromagnetic waves with wavelengths in the range of 0.1 Å to 100 Å (or 0.01 to 10 nm) belong to the X-ray region.
Final Answer: X-rays

Answer: (C)

Q20.

Solution

Concept: In a head-on elastic collision between a moving mass m_1 (velocity v_1) and a stationary mass m_2, the final velocity of the second mass v_2' is:

$$v_2' = \left(\frac{2m_1}{m_1 + m_2}\right) v_1$$

To complete a vertical circle of radius r, the minimum speed required at the bottom is $\sqrt{5gr}$.

Solution: 1. First collision: $m_1 = m$, $m_2 = m/2$, $v_1 = u$.

$$v_2' = \left(\frac{2m}{m + m/2}\right) u = \left(\frac{2m}{3m/2}\right) u = \frac{4}{3}u$$

2. Second collision: $m_1 = m/2$, $m_2 = m/4$, $v_1 = \frac{4}{3}u$.

$$v_3' = \left(\frac{2(m/2)}{m/2 + m/4}\right)\left(\frac{4}{3}u\right) = \left(\frac{m}{3m/4}\right)\frac{4}{3}u = \frac{4}{3}\left(\frac{4}{3}u\right) = \left(\frac{4}{3}\right)^2 u$$

3. Following the pattern, for n balls (requiring $n-1$ collisions), the speed of the n^{th} ball v_n is:

$$v_n = \left(\frac{4}{3}\right)^{n-1} u$$

4. Set $v_n = \sqrt{5gr}$ and solve for u:

$$\sqrt{5gr} = \left(\frac{4}{3}\right)^{n-1} u \implies u = \frac{\sqrt{5gr}}{(4/3)^{n-1}} = \left(\frac{3}{4}\right)^{n-1} \sqrt{5gr}$$

Final Answer: $(3/4)^{n-1}\sqrt{5gr}$

Answer: (A)

Q21.

Solution

Concept: When a metal ring is heated, its circumference increases, allowing it to fit over the wooden wheel. Upon cooling by ΔT, the ring attempts to contract to its original length. Since the rigid wooden wheel prevents this contraction, a thermal strain is developed, leading to a tension T within the ring.

Solution: 1. The thermal strain produced in the ring is given by:

$$\text{Strain} = \frac{\Delta L}{L} = \alpha \Delta T$$

2. According to Young's modulus ($Y = \text{Stress}/\text{Strain}$), the thermal stress in the ring is:

$$\text{Stress} = Y \times \text{Strain} = Y\alpha\Delta T$$

3. The tension (T) developed in the cross-sectional area S of the ring is:

$$T = \text{Stress} \times S = SY\alpha\Delta T$$

4. Consider one semicircular part of the wheel. The ring crosses the junction between the two halves at two points. At each point, the tension T in the ring pulls the two halves together. 5. Therefore, the total force F with which one half is pressed against the other is the sum of the tensions at both ends:

$$F = 2T = 2SY\alpha\Delta T$$

Final Answer: $2SY\alpha\Delta T$

Answer: (B)

Q22.

Solution

Concept: In an isobaric process (constant pressure), the heat supplied (Q) and the work done (W) are related through the molar heat capacities. For n moles of an ideal gas, $Q = nC_p\Delta T$ and $W = P\Delta V = nR\Delta T$.

[Image of isobaric process on a PV diagram]

Solution: 1. We have the total heat supplied:

$$Q = nC_p\Delta T$$

2. We have the work done:

$$W = nR\Delta T$$

3. Taking the ratio of Q to W:

$$\frac{Q}{W} = \frac{nC_p\Delta T}{nR\Delta T} = \frac{C_p}{R}$$

4. Using the relations $C_p - C_v = R$ and $\gamma = C_p/C_v$, we can express R as:

$$R = C_p - \frac{C_p}{\gamma} = C_p\left(\frac{\gamma - 1}{\gamma}\right)$$

5. Substitute R back into the ratio:

$$\frac{Q}{W} = \frac{C_p}{C_p(\frac{\gamma-1}{\gamma})} = \frac{\gamma}{\gamma - 1}$$

6. Solving for Q:

$$Q = \frac{W\gamma}{\gamma - 1}$$

Final Answer: $W\gamma/(\gamma - 1)$

Answer: (A)

Q23.

Solution

Concept: A neutron in thermal equilibrium with a medium at temperature T is called a thermal neutron. Its average kinetic energy (K) is determined by the kinetic theory of gases: $K = \frac{3}{2}kT$, where k is the Boltzmann constant. The de-Broglie wavelength is given by $\lambda = h/p$.

Solution: 1. The relationship between momentum (p) and kinetic energy (K) is:

$$p = \sqrt{2mK}$$

2. Substitute the thermal kinetic energy $K = \frac{3}{2}kT$:

$$p = \sqrt{2m\left(\frac{3}{2}kT\right)} = \sqrt{3mkT}$$

3. Substitute the momentum into the de-Broglie equation:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{3mkT}}$$

Final Answer: $h/\sqrt{3mkT}$

Answer: (B)

Q24.

Solution

Concept: Angular acceleration (α) is the rate of change of angular velocity (ω). It is calculated using the formula:

$$\alpha = \frac{\omega_f - \omega_i}{t}$$

where $\omega = 2\pi f$ and f is the frequency in revolutions per second (rps).

Solution: 1. Convert initial frequency from rpm to rps:

$$f_i = \frac{360}{60} = 6 \text{ rps} \implies \omega_i = 2\pi(6) = 12\pi \text{ rad/s}$$

2. Convert final frequency from rpm to rps:

$$f_f = \frac{1200}{60} = 20 \text{ rps} \implies \omega_f = 2\pi(20) = 40\pi \text{ rad/s}$$

3. Calculate the angular acceleration with $t = 14$ s:

$$\alpha = \frac{40\pi - 12\pi}{14} = \frac{28\pi}{14} = 2\pi \text{ rad/s}^2$$

Final Answer: 2π rad/s^2

Answer: (A)

Q25.

Solution

Concept: Stress is defined as the restoring force per unit area.

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

Solution: 1. The dimensional formula for Force ($F = ma$) is:

$$[F] = [M][LT^{-2}] = [MLT^{-2}]$$

2. The dimensional formula for Area ($A = L^2$) is:

$$[A] = [L^2]$$

3. Dividing the dimensions of force by the dimensions of area:

$$\text{Dimensions of Stress} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$$

Final Answer: $[ML^{-1}T^{-2}]$

Answer: (C)

Q26.

Solution

Concept: The work done in a cyclic process on a $P - V$ diagram is equal to the area enclosed by the loop. The sign of the work depends on the direction: clockwise is positive (work done by the gas), and anticlockwise is negative (work done on the gas).

Solution: 1. The path is a triangle with vertices $A(V_1, P_1)$, $B(2V_1, P_1)$, and $C(V_1, 4P_1)$. 2. Base of the triangle (along AB) = $2V_1 - V_1 = V_1$. 3. Height of the triangle (along AC) = $4P_1 - P_1 = 3P_1$. 4. Area = $\frac{1}{2} \times \text{Base} \times \text{Height} = \frac{1}{2} \times V_1 \times 3P_1 = 1.5P_1V_1$. 5. Since the path is **anticlockwise**, the net work done is negative: $W = -1.5P_1V_1$.

Final Answer: $-1.5P_1V_1$.

Answer: (C)

Q27.

Solution

Concept: For an object to leave the Earth's gravitational influence forever, its velocity must be at least equal to the escape velocity (v_e).

Solution: 1. The escape velocity from the surface of a planet is $v_e = \sqrt{\frac{2GM}{R}}$. 2. If $v = v_e$, the object reaches infinity with zero kinetic energy (it "just" escapes). 3. If $v > v_e$, the object reaches infinity with some residual kinetic energy. 4. Therefore, to ensure it does not return, the condition is $v \geq \sqrt{2GM/R}$.

Final Answer: $v \geq \sqrt{2GM/R}$.

Answer: (C)

Q28.

Solution

Concept: Magnetic materials are classified based on their response to external magnetic fields. Ferromagnetic materials are those that exhibit strong, permanent magnetization. This occurs because their atoms have permanent magnetic dipoles that align in groups called domains.

Solution: 1. **Ferromagnetic metals:** These include Iron (Fe), Cobalt (Co), and Nickel (Ni). They have high magnetic susceptibility and can be permanently magnetized. 2. **Paramagnetic/Other:** Manganese (Mn) is paramagnetic at room temperature, though it can exhibit different properties in alloys. Platinum (Pt) is also paramagnetic. 3. **Diamagnetic:** Copper (Cu) and Gold (Au) are diamagnetic (weakly repelled by magnetic fields). 4. Therefore, the group consisting solely of ferromagnetic metals is Fe, Co, and Ni.

Final Answer: Fe, Co, Ni

Answer: (B)

Q29.

Solution

Concept: When a photon of wavelength λ hits a surface, its energy is $E_p = hc/\lambda$. If the work function is negligible, all this energy is converted into the kinetic energy (K) of the emitted photoelectron. The de-Broglie wavelength of the electron is $\lambda_d = h/p$.

Solution: 1. The relationship between kinetic energy and momentum is $K = p^2/2m$. 2. From de-Broglie's equation, $p = h/\lambda_d$. Substituting this into the energy equation:

$$K = \frac{(h/\lambda_d)^2}{2m} = \frac{h^2}{2m\lambda_d^2}$$

3. Equating the photon energy to the electron's kinetic energy:

$$\frac{hc}{\lambda} = \frac{h^2}{2m\lambda_d^2}$$

4. Rearranging for λ:

$$\lambda = \frac{hc \cdot 2m\lambda_d^2}{h^2} = \left(\frac{2mc}{h}\right)\lambda_d^2$$

Final Answer: $\lambda = (2mc/h)\lambda_d^2$

Answer: (A)

Q30.

Solution

Concept: We must compare the de-Broglie wavelength of a matter particle (electron) and a quantum of light (photon) when they possess the same energy E.

Solution: 1. **For the Photon (λ_p):** Using $E = hc/\lambda_p$, we get:

$$\lambda_p = \frac{hc}{E}$$

2. **For the Electron (λ_e):** Using $E = p^2/2m$, we find $p = \sqrt{2mE}$. Then:

$$\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$$

3. **Calculating the Ratio:**

$$\frac{\lambda_e}{\lambda_p} = \frac{h/\sqrt{2mE}}{hc/E} = \frac{h}{\sqrt{2mE}} \cdot \frac{E}{hc}$$

$$\frac{\lambda_e}{\lambda_p} = \frac{E}{c\sqrt{2mE}} = \frac{1}{c}\sqrt{\frac{E^2}{2mE}} = \frac{1}{c}\sqrt{\frac{E}{2m}}$$

Final Answer: $\frac{1}{c}\sqrt{E/2m}$

Answer: (A)

Q31.

Solution

Concept: Efficiency (η) of a transformer is defined as the ratio of output power (P_{out}) to input power (P_{in}). In the secondary coil, $P_{out} = V_s \times I_s$.

Solution: 1. Given: $P_{in} = 3$ kW $= 3000$ W, $\eta = 90\% = 0.9$. 2. Calculate the output power:

$$P_{out} = \eta \times P_{in} = 0.9 \times 3000 = 2700 \text{ W}$$

3. Use the secondary current ($I_s = 6$ A) to find the secondary voltage (V_s):

$$P_{out} = V_s \times I_s \implies 2700 = V_s \times 6$$

$$V_s = \frac{2700}{6} = 450 \text{ V}$$

Final Answer: 450 V

Answer: (B)

Q32.

Solution

Concept: Radioactive decay is statistical. The amount of substance remaining (N) after a time t is given by $N = N_0(1/2)^n$, where n is the number of half-lives. Decay percentage is $(1 - N/N_0) \times 100$.

Solution: 1. **At 20% decay:** 80% of the substance remains ($N_1 = 0.8N_0$). 2. **At 80% decay:** 20% of the substance remains ($N_2 = 0.2N_0$). 3. Find the ratio of remaining amounts:

$$\frac{N_1}{N_2} = \frac{0.8N_0}{0.2N_0} = 4$$

4. Since $4 = 2^2$, the time interval between these two states corresponds to exactly **2 half-lives**.
5. Given half-life $t_{1/2} = 20$ min:

$$\text{Total time} = 2 \times 20 = 40 \text{ min}$$

Final Answer: 40 min

Answer: (B)

Q33.

Solution

Concept: The power of a lens (P) is the reciprocal of its focal length. When two thin lenses are placed in contact, the total power of the combination is the algebraic sum of the individual powers: $P_{eq} = P_1 + P_2$.

Solution: 1. For the convex lens: $f_1 = +f$, so $P_1 = 1/f$. 2. For the concave lens: $f_2 = -f$, so $P_2 = -1/f$. 3. Total power:

$$P_{eq} = P_1 + P_2 = \frac{1}{f} + \left(-\frac{1}{f}\right) = 0$$

4. The equivalent focal length (F_{eq}) is the reciprocal of the total power:

$$F_{eq} = \frac{1}{P_{eq}} = \frac{1}{0} = \infty$$

5. Physically, this means the combination acts like a plane glass sheet, and parallel rays remain parallel.

Final Answer: Infinite

Answer: (D)

Q34.

Solution

Concept: Penetrating power refers to the ability of radiation to pass through matter. It is inversely proportional to the size and charge of the particle/radiation.

Solution: 1. **α-rays:** Helium nuclei with +2 charge and large mass. They are easily stopped by a sheet of paper. 2. **β-rays:** Fast-moving electrons with -1 charge. They can penetrate paper but are stopped by a thin aluminum plate. 3. **γ-rays:** High-energy electromagnetic radiation (photons) with no mass and no charge. They have the highest frequency and can only be stopped by thick layers of lead or concrete. 4. **X-rays:** Also EM waves, but generally have lower energy/longer wavelengths than γ-rays, resulting in lower penetration.

Final Answer: γ-rays

Answer: (C)

Q35.

Solution

Concept: Velocity is a vector quantity. Even if the speed v is constant in circular motion, the direction changes, leading to a change in velocity ($\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$).

Solution: 1. Let the magnitude of initial and final velocities be $|\vec{v}_1| = |\vec{v}_2| = v$. 2. The angle between the two velocity vectors is the same as the angle rotated, θ. 3. The magnitude of the change in velocity is given by the vector subtraction formula:

$$|\Delta\vec{v}| = \sqrt{v^2 + v^2 - 2v^2\cos\theta}$$

4. Factor out $2v^2$:

$$|\Delta\vec{v}| = \sqrt{2v^2(1 - \cos\theta)}$$

5. Use the trigonometric identity $1 - \cos\theta = 2\sin^2(\theta/2)$:

$$|\Delta\vec{v}| = \sqrt{2v^2 \cdot 2\sin^2(\theta/2)} = \sqrt{4v^2\sin^2(\theta/2)}$$

$$|\Delta\vec{v}| = 2v\sin(\theta/2)$$

Final Answer: $2v\sin(\theta/2)$

Answer: (A)

Q36.

Solution

Concept: For a highly symmetric charge distribution like an infinite wire, we use Gauss's Law: $\oint \vec{E} \cdot d\vec{A} = \frac{q_{enclosed}}{\epsilon_0}$.

Solution: 1. Consider a cylindrical Gaussian surface of radius r and length L around the wire. 2. The total enclosed charge is $q = \lambda L$. 3. The electric flux through the curved surface is $E \times (2\pi r L)$ (flux through the ends is zero). 4. Applying Gauss's Law:

$$E(2\pi r L) = \frac{\lambda L}{\epsilon_0}$$

5. Solving for E:

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

Final Answer: $\lambda/2\pi\epsilon_0 r$

Answer: (A)

Q37.

Solution

Concept: In YDSE, the fringe width β is given by $\beta = \frac{\lambda D}{d}$, where λ is the wavelength in the medium. When light enters a medium of refractive index μ, its speed and wavelength change.
Solution: 1. The wavelength of light in a liquid of refractive index μ is $\lambda' = \frac{\lambda_{air}}{\mu}$. 2. The new fringe width β' is:

$$\beta' = \frac{\lambda' D}{d} = \frac{(\lambda_{air}/\mu)D}{d}$$

3. Since the original fringe width in air is $\beta = \frac{\lambda_{air} D}{d}$, we can substitute it into the expression:

$$\beta' = \frac{\beta}{\mu}$$

Final Answer: β/μ

Answer: (C)

Q38.

Solution

Concept: In an astronomical telescope, "normal adjustment" means the final image is formed at infinity. In this state, the magnifying power (M) is defined as the ratio of the focal length of the objective (f_o) to the focal length of the eyepiece (f_e).
Solution: 1. Identify the given values: * Focal length of objective (f_o) = 100 cm * Focal length of eyepiece (f_e) = 5 cm 2. The formula for magnifying power in normal adjustment is:

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

3. Substitute the values:

$$M = \frac{100}{5} = 20$$

Final Answer: 20

Answer: (A)

Q39.

Solution

Concept: The resistance (R) of a wire is given by $R = \rho \frac{L}{A}$, where ρ is resistivity, L is length, and A is cross-sectional area. When a wire is stretched, its volume ($V = A \cdot L$) remains constant.

Solution: 1. Let the initial length and area be L and A. Let the new length be $L' = nL$. 2. Since volume is constant: $V = A \cdot L = A' \cdot L'$. 3. Substitute L': $A \cdot L = A' \cdot (nL) \implies A' = \frac{A}{n}$. 4. The new resistance R' is:

$$R' = \rho \frac{L'}{A'} = \rho \frac{nL}{A/n} = n^2 \left(\rho \frac{L}{A} \right)$$

5. Since $R = \rho \frac{L}{A}$, we get:

$$R' = n^2 R$$

Final Answer: $n^2 R$

Answer: (C)

Q40.

Solution

Concept: The magnetic field produced by a current-carrying loop can be derived using the Biot-Savart Law. For a circular loop, the field at the center is perpendicular to the plane of the loop.

Solution: 1. According to the Biot-Savart Law, for a small element dl at the center: $dB = \frac{\mu_0}{4\pi} \frac{I \cdot dl \cdot \sin\theta}{R^2}$. 2. For a circular loop, the angle between dl and the radius vector is always 90°, so $\sin 90^\circ = 1$. 3. Integrating around the loop:

$$B = \oint \frac{\mu_0}{4\pi} \frac{I \cdot dl}{R^2} = \frac{\mu_0 I}{4\pi R^2} \oint dl$$

4. Since the circumference $\oint dl = 2\pi R$:

$$B = \frac{\mu_0 I}{4\pi R^2}(2\pi R) = \frac{\mu_0 I}{2R}$$

Final Answer: $\mu_0 I / 2R$

Answer: (A)

Q41.

Solution

Concept: For a photon, which is a massless particle traveling at the speed of light (c), the relationship between energy (E) and momentum (p) is derived from Einstein's mass-energy equivalence and Planck's equation.

Solution: 1. The energy of a photon is $E = h\nu$ and its momentum is $p = \frac{h}{\lambda} = \frac{h\nu}{c}$. 2. Combining these, we find the direct relationship:

$$E = pc \implies p = \frac{E}{c}$$

3. Since c is a constant, momentum is directly proportional to energy ($p \propto E$). 4. If the energy is tripled ($E' = 3E$), then the new momentum p' will be:

$$p' = \frac{3E}{c} = 3p$$

Final Answer: Become 3 times

Answer: (A)

Q42.

Solution

Concept: The resistance of a uniform wire is directly proportional to its length ($R \propto L$). When a wire is bent into a circle, the points that are diametrically opposite divide the wire into two equal segments, each forming a semi-circle. These two segments are connected in parallel between the two points.

Solution: 1. The total resistance of the wire of length L is R. 2. When divided into two equal semi-circles, the length of each part is $L/2$. 3. Therefore, the resistance of each semi-circular segment is $R_1 = R_2 = R/2$. 4. These two resistors are in parallel between the diametrically opposite points. 5. The equivalent resistance (R_{eq}) for two identical resistors in parallel is:

$$R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{(R/2) \times (R/2)}{(R/2) + (R/2)} = \frac{R^2/4}{R} = \frac{R}{4}$$

Final Answer: $R/4$

Answer: (C)

Q43.

Solution

Concept: Einstein's photoelectric equation states that the energy of an incident photon (E) is used to overcome the work function (ϕ) of the metal and provide the maximum kinetic energy (K_{max}) to the emitted photoelectron.

$$E = \phi + K_{max}$$

The stopping potential (V_0) is related to the maximum kinetic energy by the relation $K_{max} = eV_0$.
Solution: 1. Given the work function $\phi = 4.2$ eV. 2. Given the stopping potential $V_0 = 3$ V. 3. The maximum kinetic energy in electron-volts is numerically equal to the stopping potential:

$$K_{max} = 3 \text{ eV}$$

4. Calculate the total energy of the incident photon:

$$E = \phi + K_{max}$$

$$E = 4.2 \text{ eV} + 3 \text{ eV} = 7.2 \text{ eV}$$

Final Answer: 7.2 eV

Answer: (B)

Q44.

Solution

Concept: Semiconductors are doped with specific impurities to change their electrical properties. A p-type (positive-type) semiconductor is created by doping an intrinsic semiconductor (like Silicon) with trivalent impurity atoms (like Boron, Aluminum, or Indium).
Solution: 1. Trivalent impurities have three valence electrons. When they bond with four-valence Silicon atoms, one bond remains incomplete. 2. This creates a vacancy known as a **hole**, which acts as a positive charge carrier. 3. Because the number of holes greatly exceeds the number of free electrons in this material, holes are the **majority charge carriers**. 4. Electrons are the minority charge carriers in p-type semiconductors.
Final Answer: Holes

Answer: (B)

Q45.

Solution

Concept: Binding energy per nucleon (BE/A) is a measure of the stability of a nucleus. A higher binding energy per nucleon indicates a more stable nucleus. The relationship is typically represented by the binding energy curve.

Solution: 1. The binding energy curve shows that BE/A is low for very light nuclei, increases to a peak, and then gradually decreases for very heavy nuclei. 2. The peak of the curve occurs for elements with a mass number around $A = 56$. 3. Iron (^{56}Fe) has the highest binding energy per nucleon (approximately 8.8 MeV per nucleon), making it the most stable nucleus. 4. ^{2}H (Deuterium) and ^{4}He are on the rising part of the curve, while ^{238}U is on the declining part.

Final Answer: ^{56}Fe

Answer: (B)

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	D	2	C	3	B	4	D	5	D
6	A	7	A	8	B	9	D	10	A
11	A	12	D	13	A	14	C	15	A
16	C	17	A	18	D	19	C	20	A
21	B	22	A	23	B	24	A	25	C
26	C	27	C	28	B	29	A	30	A
31	B	32	B	33	D	34	C	35	A
36	A	37	C	38	A	39	C	40	A
41	A	42	C	43	B	44	B	45	B