Test Your fiziks concepts!

Topic: Quantum Mechanics

(For CSIR NET-JRF, GATE, JEST and TIFR Aspirants)

Q. The non-relativistic Hamiltonian for a single electron atom is $H_0 = \frac{p^2}{2m} - V(r)$ where $V(r)$ is the Coulomb potential and m is the mass of the electron. Considering the spin-orbit interaction term $H' = \frac{1}{2m^2c^2}\frac{1}{r}\frac{dV}{dr}\vec{L}\cdot\vec{S}$ added to H_0, which of the following statement is not true?

(a) H' commutes with L^2

(b) H' commutes with L_z and S_z

(c) For a given value of principal quantum number n and orbital angular momentum quantum number l, there are $2(2l+1)$ degenerate eigenstates of H_0

(d) H_0, L^2, S^2, L_z and S_z have a set of simultaneous eigenstates

Ans.: (b)

Solution.: (a) $\left[H', L^2\right] = \frac{1}{2m^2c^2}\frac{1}{r}\frac{dV}{dr}\left[\vec{L}\cdot\vec{S}, L^2\right]$

Since $\left[L^2, L_i\right] = 0$ and $\left[L^2, S_i\right] = 0$. Therefore $\left[\vec{L}\cdot\vec{S}, L^2\right] = 0$. Thus $\left[H', L^2\right] = 0$

The statement (a) is correct.

(b) $\left[H', L_z\right] = \frac{1}{2m^2c^2}\frac{1}{r}\frac{dV}{dr}\left[\vec{L}\cdot\vec{S}, L_z\right]$. Now $\left[\vec{L}\cdot\vec{S}, L_z\right] = \left[L_xS_x + L_yS_y + L_zS_z, L_z\right]$

Since $\left[L_i, L_j\right] = i\hbar \in_{ijk} L_k$. Therefore $\left[\vec{L}\cdot\vec{S}, L_z\right] \neq 0$, thus statement (b) is not correct.

(c) For given value of n and ℓ, the degeneracy is $g = 2\ell(\ell+1)$

Thus statement (c) is correct.

(d) The unperturbed Hamiltonian H_0 is spherically symmetric and depends only on r.

Thus $\left[H, L^2\right] = 0$ and $\left[H, L_z\right] = 0$

H also commutes with S^2 and S_z, because H does not depend on the spin degree of freedom.

$\left[H, S^2\right] = 0$ and $\left[H, S_z\right] = 0$. Thus statement (d) is correct.

The incorrect statements is (b).

Note:

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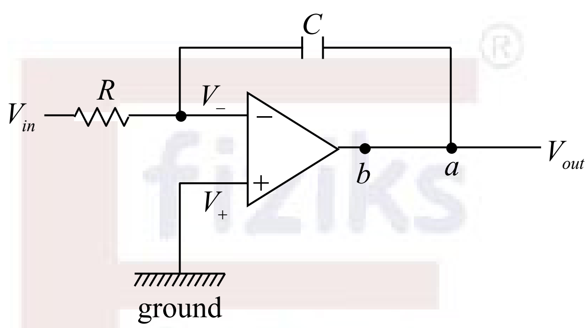
Test Your fiziks concepts!

Topic: Electronics

(For IIT-JAM, JEST, TIFR and CUET Aspirants)

Q. The gain of the circuit given below is $-1/\omega RC$.



The modification in the circuit required to introduce a dc feedback is to add a resistor

(a) Between a and b

(b) Between positive terminal of the op-amp and ground

(c) In series with C

(d) Parallel to C

Ans.: (d)

Note:

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Test Your fiziks concepts!

Topic: Modern Physics

(For PGT: KVS, NVS, DSSSB, State Education Boards, etc.)

Q. The magnitudes of spin magnetic moments of electron, proton and neutron are μ_e, μ_p and μ_n, respectively. Then,

(a) $\mu_e > \mu_p > \mu_n$

(b) $\mu_e = \mu_p > \mu_n$

(c) $\mu_e < \mu_p < \mu_n$

(d) $\mu_e < \mu_p = \mu_n$

Ans.: (a)

Solution.:

The spin magnetic moment (μ) of a particle is given by the expression:

$$\vec{\mu} = g\frac{q}{2m}\vec{S}$$

where, g is Gyromagnetic ratio, q is Charge of the particle, m is Mass of the particle, and S is Spin angular momentum.

The spin magnetic moments of particles are inversely proportional to their masses. Thus, the electron has the smallest mass, resulting in the largest magnetic moment (μ_e). The proton has a mass much larger than the electron but smaller than the neutron, giving it a magnetic moment (μ_p) smaller than the electron. The neutron has the largest mass among the three particles, resulting in the smallest magnetic moment (μ_n). Based on their masses and the given expression, the order of magnetic moments is: $\mu_e > \mu_p > \mu_n$. Thus, the correct option is (a).

Note:

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Test Your fiziks concepts!

Topic: Quantum Mechanics

(For CSIR NET-JRF, GATE, JEST and TIFR Aspirants)

Q. Following trial wavefunctions $\phi_1 = e^{-Z'(r_1+r_2)}$ and $\phi_2 = e^{-Z'(r_1+r_2)}\left(1+g\left|\vec{r}_1-\vec{r}_2\right|\right)$ are used to get a variational estimate of the ground state energy of the helium atom. Z' and g are the variational parameters, $\vec{r}_1$ and $\vec{r}_2$ are the position vectors of the electrons. Let E_0 be the exact ground state energy of the helium atom. E_1 and E_2 are the variational estimates of the ground state energy of the helium atom corresponding to ϕ_1 and ϕ_2, respectively. Which one of the following options is true?

(a) $E_1 \le E_0, E_2 \le E_0, E_1 \ge E_2$

(b) $E_1 \ge E_0, E_2 \le E_0, E_1 \ge E_2$

(c) $E_1 \le E_0, E_2 \ge E_0, E_1 \le E_2$

(d) $E_1 \ge E_0, E_2 \ge E_0, E_1 \ge E_2$

Ans.: (d)

Solution.: Variational principle always gives an upper bound to ground state energy (E_0)

$\therefore\ E_1 \ge E_0$ and $E_2 \ge E_0$

only option (d) satisfying the condition. Therefore, option (d) is correct answer.

Note:

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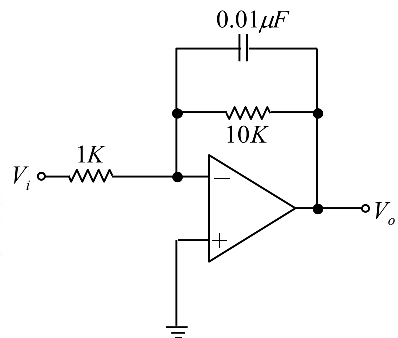
Test Your fiziks concepts!

Topic: Electronics

(For IIT-JAM, JEST, TIFR and CUET Aspirants)

Q. In the op-amp circuit shown in the figure, V_i is a sinusoidal input signal of frequency $10\,Hz$ and V_0 is the output signal. The magnitude of the gain and the phase shift, respectively, close to the values



(a) $5\sqrt{2}$ and $\pi/2$

(b) $5\sqrt{2}$ and $-\pi/2$

(c) 10 and zero

(d) 10 and π

Ans.: (d)

Solution.: $\frac{v_o}{v_{in}} = -\frac{X_F}{R_1}$, $X_F = \frac{R_F X_C}{R_F + X_C}$

where $R_1 = 10^3\Omega, R_F = 10^4\Omega$, $X_C = \frac{1}{j\omega C} = \frac{1}{j \times 10 \times 10^{-8}} = -j10^7\Omega$

$$\Rightarrow \frac{v_0}{v_{in}} = -\frac{10^4\Omega\left(-j10^7\Omega\right)}{10^3\Omega\left(10^4\Omega - j10^7\Omega\right)} = \frac{j10^{11}}{10^3\left(10^4 - j10^7\right)} = \frac{j10^4}{\left(1 - j10^3\right)} = \frac{10^4 e^{j\pi/2}}{\sqrt{1+10^6}e^{-j\theta}} = \frac{10^4}{10^3}e^{j(\pi/2+\theta)}$$

Where $\theta = \tan^{-1}(1000) = 1.57 = \frac{\pi}{2}$.

$$\Rightarrow \left|\frac{v_0}{v_{in}}\right| \approx 10 \text{ and phase shift } \phi = \theta + \frac{\pi}{2} = \pi.$$

Note:

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Test Your fiziks concepts!

Topic: Modern Physics

(For PGT: KVS, NVS, DSSSB, State Education Boards, etc.)

Q. Given that the rest mass of electron is $0.511\,\text{MeV}/c^2$, the speed (in units of c) of an electron with kinetic energy 5.11MeV is closest to:

(a) 0.996 (b) 0.993 (c) 0.990 (d) 0.998

Ans.: (a)

Solution.: $E = K + m_0c^2 = (10\times 0.511) + 0.511$

$$\frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}} = 11\times 0.511 \Rightarrow 1-\frac{v^2}{c^2} = \frac{1}{(11)^2} = \frac{1}{121} \Rightarrow \frac{v^2}{c^2} = \frac{120}{121} \Rightarrow v = \sqrt{\frac{120}{121}}c = 0.9958c \cong 0.996c$$

Note:

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