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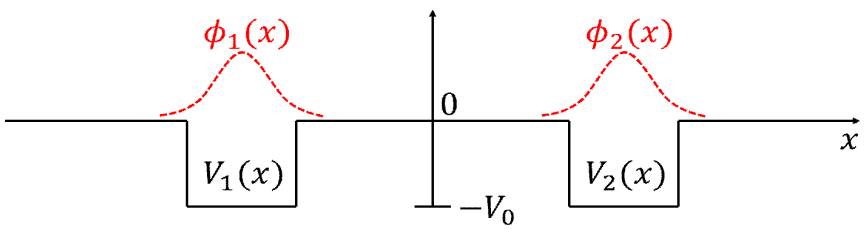
2014학년도 석사과정/석사·박사통합과정
전기모집 면접·구술고사 전공시험

과목명 : 물리 2013. 10. 25 시행

1. <70 points> Consider a particle in two identical one-dimensional square wells. For wells with sufficiently large separation, let us introduce ϕ_1 and ϕ_2 as the normalized ground-state wave functions of the two isolated square wells. Assume that these wave functions are real and positive.



If the two wells are not very far from each other, ϕ_1 and ϕ_2 are no longer eigenstates of the system and as a good approximation, we can write the ground-state wave function as a linear combination of ϕ_1 and ϕ_2, $\Psi = c_1\phi_1 + c_2\phi_2$.

Define $H_{11} = \langle\phi_1|H|\phi_1\rangle = \langle\phi_2|H|\phi_2\rangle$ and $H_{12} = \langle\phi_1|H|\phi_2\rangle$, $S_{12} = \langle\phi_1|\phi_2\rangle$, and assume that c_1, c_2, H_{11}, H_{12} and S_{12} are real.

(a) (5 points) Express $E = \dfrac{\langle\Psi|H|\Psi\rangle}{\langle\Psi|\Psi\rangle}$ using c_1, c_2, H_{11}, H_{12} and S_{12}.

(b) (15 points) The coefficients c_1 and c_2 can be estimated by minimizing the energy defined by $E = \dfrac{\langle\Psi|H|\Psi\rangle}{\langle\Psi|\Psi\rangle}$. Prove that c_1 and c_2 satisfy the following relation.

$$\begin{pmatrix} H_{11} & H_{12} \\ H_{12} & H_{11} \end{pmatrix}\begin{pmatrix} c_1 \\ c_2 \end{pmatrix} = E\begin{pmatrix} 1 & S_{12} \\ S_{12} & 1 \end{pmatrix}\begin{pmatrix} c_1 \\ c_2 \end{pmatrix}$$

From now on, let's set $S_{12} = 0$ for simplicity.

(c) (10 points) Obtain the ground-state energy and excited state energy. Assuming H_{12}<0, discuss whether the ground-state wave function is spatially symmetric or antisymmetric and draw schematically the density distribution.

Now, for (d) and (e), assume that H_{11}=−10 eV and H_{12}=−1 eV.

(d) (10 points) Imagine that using a laser, we excite the particle from the ground state to the excited state. What is the proper wavelength and corresponding color of the laser for the excitation?

(e) (10 points) Assume that at a time $t = 0$, the particle is at state ϕ_1. Obtain the minimum time that the particle is found 100 % at state ϕ_2. Express the answer first with symbols (using H_{11} and H_{12}), and then estimate the order of magnitude in seconds.

Now, we want to test this theoretical model for the two quantum wells which are closely located as given in this problem. (It does not have to be one-dimensional system.)

(f) (10 points) Design the experimental setup to test the energy levels of the quantum wells.

(g) (10 points) Explain the experimental procedure for this experiment and discuss the expected data and results.

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[2]<30 points> Consider a particle of charge q and mass m, free to move in the x–y plane (at z =0) in response to an electromagnetic wave propagating in the z direction represented as:

$\vec{E}(z,t) = E_0\cos(kz - wt)\hat{x}$

$\vec{B}(z,t) = (E_0/c)\cos(kz - wt)\hat{y}$

There exists resisting force to the motion of the charged particle in the form of $-\gamma m\vec{v}$ with a small damping constant γ.

(a) (10 points) Ignoring the magnetic force, write down the equation of motion in terms of $\vec{v}$.

(b) (10 points) Using the equation of motion obtained in (a), find the velocity $\vec{v}$ of the particle as a function of time. The initial conditions are given as

$\vec{v}(t=0) = x(t=0) = y(t=0) = 0.$

(c) (10 points) Calculate the resulting magnetic force on the particle using the result of (b).