MANIPAL ACADEMY of HIGHER EDUCATION
(Deemed to be University under Section 3 of the UGC Act, 1956)

Reg. No.

DEPARTMENT OF SCIENCES, M. Sc. (Physics)
II SEMESTER, END SEMESTER EXAMINATIONS
JUNE 2019
Subject: Quantum Mechanics II (PHY-4206)
(REVISED CREDIT SYSTEM - 2017)

Time: 3 Hours   Date: June 2019   MAX. MARKS: 50

Note: (i) Answer all the questions.
(ii) Answer the questions to the point.

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1. (i) Derive matrix for J_z operator for $j = \frac{3}{2}$. [5]
(ii) Optimize the trial function $exp(-\alpha r)$ and evaluate the ground state energy of the hydrogen atom. [5]
2. (i) Solve the following one dimensional infinite potential well:

$$V(x) = 0 \quad \textbf{for} - a < x < a; \quad V(x) = \infty \quad \textbf{for} |x| > a$$

using the WKB method and compare it with the exact solution. [3]
(ii) Mention the validity condition of the WKB method. [2]
(iii) By applying the WKB method connection formulae obtain expression for energy levels of a particle in a potential well. [5]
3. (i) Briefly discuss the time dependent perturbation theory for a two level system. [5]
(ii) A system is in an unperturbed state n is suddenly subjected to a constant perturbation $H'(r)$ which exists during time $0 \rightarrow t$. Find the probability for transition from state n to state k and show that it varies simple harmonically with
angular frequency= $\frac{E_k - E_n}{2\hbar}$ and amplitude= $4\frac{|H'_{kn}|^2}{(E_k - E_n)^2}$. [5]
4. (i) Using first order Born approximation for weak and spherically symmetric potential obtain expression of scttering amplitude. [5]
(ii) Calculate the scattering amplitude for a particle moving in the potential

$$V(r) = C\frac{c - r}{r}exp\left(-\frac{r}{r_0}\right)$$

where C and r_0 are constants. [5]
5. (i) Using the Klein - Gordon equation show that the expression

for relativistic and non - relativistic charge densities are different. [5]
(ii) Show that the Dirac matrices are traceless and can be of even order only. [5]

Useful formulae:

$$\nabla^2 t = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial t}{\partial r}\right) + \frac{1}{r^2 sin\theta}\frac{\partial}{\partial \theta}\left(sin\theta\frac{\partial t}{\partial \theta}\right) + \frac{1}{r^2 sin^2\theta}\frac{\partial^2 t}{\partial \phi^2}$$

$$\int_0^\infty x^n exp(-ax)\,dx = \frac{n!}{a^{n+1}}, \quad \textbf{where} \quad n \geq 0, \quad a > 0$$

Barrier to the right of the turning point

$$\frac{2}{\sqrt{k}}cos\left(\int_x^{x_1} k\,dx - \frac{\pi}{4}\right) \longleftarrow \frac{1}{\sqrt{\gamma}}exp\left(-\int_{x_1}^{x} \gamma\,dx\right)$$

$$\frac{1}{\sqrt{k}}sin\left(\int_x^{x_1} k\,dx - \frac{\pi}{4}\right) \longrightarrow -\frac{1}{\sqrt{\gamma}}exp\left(\int_{x_1}^{x} \gamma\,dx\right)$$

Barrier to the left of the turning point

$$\frac{1}{\sqrt{\gamma}}exp\left(-\int_x^{x_2} \gamma\,dx\right) \longrightarrow \frac{2}{\sqrt{k}}cos\left(\int_{x_2}^{x} k\,dx - \frac{\pi}{4}\right)$$

$$-\frac{1}{\sqrt{\gamma}}exp\left(\int_x^{x_2} \gamma\,dx\right) \longleftarrow \frac{1}{\sqrt{k}}sin\left(\int_{x_2}^{x} k\,dx - \frac{\pi}{4}\right)$$