UGC POINT

LEADING INSTITUE FOR CSIR-JRF/NET,GATE & JAM

BOOKLET CODE **B**

SUBJECT CODE **05**

PHYSICAL SCIENCE

TEST SEREIS # 3

QUANTUM MECHANICS+ ELECTRONICS

Date: 28/5/2015
Timing: 2:00 H
Maximum Marks: 80

Instructions

1. This test paper has a total of 40 questions carrying 80 marks. All Question are compulsory
2. Read the Questions carefully and mark your appropriate response to the OMR sheet
3. There is Negative marking of 1/4 for Each wrong answer
4. Mark the response by **Black** or **Blue** Ball Pen only
5. Any other belongings like Book/ Notes / Electronic device etc are not permitted in the examination hall.
6. Submit your answer sheet (OMR Sheet) to the invigilator before leaving the examination hall

UGC POINT ACADEMY
India's Leading Institute for : CSIR, NET & GATE

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1. Consider the normalized wave function
$\Psi = a_1\phi_{11} + a_2\phi_{10} + a_3\phi_{1-1}$
Where ϕ_{lm} is a simultaneous normalized Eigen function of the angular momentum operators L^2 & L_z, with Eigen values $l(l+1)\hbar^2$ and $m\hbar$ respectively. If Ψ is an Eigen function of the operator L_y with Eigen value $\hbar$, then
(1) $a_1 = -a_3 = \frac{1}{2}, a_2 = \frac{1}{\sqrt{2}}$
(2) $a_1 = a_3 = \frac{1}{2}, a_2 = \frac{1}{\sqrt{2}}$
(3) $a_1 = a_3 = \frac{1}{2}, a_2 = -\frac{1}{\sqrt{2}}$
(4) $a_1 = a_2 = a_3 = \frac{1}{\sqrt{3}}$

2. The recoil momentum of an atom is p when it emits an infrared photon of wave length 1500 nm. What will be the emitted wave length when the recoil moment is $3p$?
(1) 500 nm (2) 1000 nm (3) 4500 nm (4) 3000 nm

3. The normalized eigen states of a particle in a one dimensional potential will
$$V(x) = \begin{cases} 0, & if \quad 0 \le x \le L \\ \infty, & otherwise \end{cases}$$
$$\phi_n(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi x}{L}\right) \text{Where } n = 1, 2, \ldots\ldots\ldots\ldots\ldots$$
The particle is subjected to a perturbation
$$V'(x) = \begin{cases} V_0 \cos\left(\frac{\pi x}{L}\right), & for \ 0 \le x \le L \\ 0, & otherwise \end{cases}$$
The shift in the ground state energy due to the perturbation, in the first order perturbation theory is
(1) $\frac{2V_0}{3\pi}$ (2) $\frac{V_0}{3\pi}$ (3) $\frac{-V_0}{3\pi}$ (4) $\frac{-2V_0}{3\pi}$

4. The commutator $[p^2, x]$ where x and p are position and momentum operators respectively is
(1) $2i\hbar p$ (2) $-i\hbar p$ (3) $-2i\hbar p$ (4) $i\hbar p$

5. For a spin 's' particle, in the Eigen basis of S_z, the expectation value $\langle sm | S_y^2 | sm \rangle$ is
(1) $\hbar^2\left[\frac{s(s+1)-m^2}{2}\right]$
(2) $\hbar^2\left[s(s+1)-2m^2\right]$
(3) $\hbar^2\left[s(s+1)-m^2\right]$
(4) $\hbar^2 m^2$

6. A particle is in the normalized state $|\Psi\rangle$ which is a superposition of the energy Eigen states $|E_0 = 20eV\rangle$ and $|E_1 = 40eV\rangle$. The average value of energy of the particle in the state $|\Psi\rangle$ is 30 *eV*. The state $|\Psi\rangle$ is given by

(1) $\frac{1}{2}|E_0 = 20eV\rangle + \frac{\sqrt{3}}{2}|E_1 = 40\,eV\rangle$ (2) $\frac{1}{\sqrt{3}}|E_0 = 20eV\rangle + \sqrt{\frac{2}{3}}|E_1 = 40\,eV\rangle$

(3) $\frac{1}{2}|E_0 = 20eV\rangle - \frac{\sqrt{3}}{4}|E_1 = 40\,eV\rangle$ (4) $\frac{1}{\sqrt{2}}|E_0 = 20eV\rangle - \frac{1}{\sqrt{2}}|E_1 = 40\,eV\rangle$

7. A particle of mass *m* is confined in the ground state of a one-dimensional box, extending from $x = -L$ to $x = L$. The wave function of the particle in this state is $\Psi(x) = a\cos\left(\frac{\pi x}{2L}\right)$. The value of *a* is

(1) $\sqrt{\frac{1}{L}}$ (2) $\sqrt{\frac{2}{L}}$ (3) $\sqrt{\frac{3}{L}}$ (4) $\frac{2}{\sqrt{L}}$

8. The value of the commutator $[p, x^3]$ is

(1) $2i\hbar x^2$ (2) $-2i\hbar x^2$ (3) $3i\hbar x^2$ (4) $3i\hbar x^2$

9. A particle of mass *m* is represented by the wave function $\Psi(x) = \frac{A}{2}e^{ikx}$, where *k* is the wave vector and A is a constant. The magnitude of the probability current density of the particle is

(1) $|A|^2 \frac{\hbar k}{4m}$ (2) $|A|^2 \frac{\hbar k}{8m}$ (3) $|A|^2 \frac{(\hbar k)^2}{4m}$ (4) $|A|^2 \frac{(\hbar k)^2}{8m}$

10. The commutator $[L_y, z]$, where L_y is the *y*-component of angular momentum operator and *z* is the *z* component of position operator, is equal to

(1) Zero (2) $i\hbar x$ (3) $-i\hbar x$ (4) $i\hbar z$

11. A particle with energy *E* encounters the potential defined as

$$V(x) = \begin{cases} 0, & x < 0 \\ V_0, & 0 \le x \le a \\ 0, & x > a \end{cases}$$

, If $E < V_0$ transmission coefficient is

(1) $\dfrac{1}{1 - \dfrac{V_0^2}{4E(V_0 - E)\sinh^2 ka}}$ (2) $\dfrac{1}{1 + \dfrac{V_0^2}{4E(V_0 - E)\sinh^2 ka}}$

(3) $\dfrac{1}{1 - \dfrac{V_0^2}{4E(V_0 + E)\sinh^2 ka}}$ (4) $\dfrac{4E(V_0 - E)}{V_0^2}$

12. A particle of mass m is confined in three dimensional potential box. The potential

$$V(x,y,z)=\begin{cases}0 & for\ \ 0\le x\le a,\ \ 0\le y\le a,\ \ 0\le z\le a\\ \infty & otherwise\end{cases}$$

The energy of second excited state is

(1) $\frac{3}{2}\frac{\hbar^2\pi^2}{ma^2}$ (2) $\frac{6\hbar^2\pi^2}{ma^2}$ (3) $\frac{9}{2}\frac{\hbar^2\pi^2}{ma^2}$ (4) $\frac{3\hbar^2\pi^2}{ma^2}$

13. The total angular momentum of electron in hydrogen atom is $\vec{J}=\vec{L}+\vec{S}$, where $\vec{L}$ and $\vec{S}$ orbital and spin angular momenta respectively. The expectation value $\langle\vec{S}.\vec{J}\rangle$ is

(1) $\frac{1}{2}\left[j(j+1)-l(l+1)+s(s+1)\right]$ (2) $\frac{1}{2}\left[j(j+1)+l(l+1)+s(s+1)\right]$

(3) $\frac{1}{2}\left[j(j+1)-l(l+1)-s(s+1)\right]$ (4) $\frac{1}{2}\left[j(j+1)-2l(l+1)-s(s+1)\right]$

14. There are three bosons and three states are available to them. Total number of distinct configuration of the system are

(1) 27 (2) 10 (3) 12 (4) 1

15. I the commutator of the parity operator Π and the Hamiltonian H is zero. Then if a system starts with odd parity then

(1) Parity of final state is even
(2) Parity of final state is odd
(3) Parity of final state is not defined
(4) Parity can be even or odd

16. The translation operator is defined as

$$T_{(\varepsilon)}=\mathbf{1}-\frac{i\varepsilon}{\hbar}P$$

Where P is linear momentum operator then

(1) $T^+_{(\varepsilon)}T_{(\varepsilon)}=\mathbf{1}$ (2) $T^+_{(\varepsilon)}T_{(\varepsilon)}=0$ (3) $T^+_{(\varepsilon)}T_{(\varepsilon)}=-\mathbf{1}$ (4) $T^+_{(\varepsilon)}T_{(\varepsilon)}=T_{(\varepsilon)}$

17. The Hamiltonian of a particle is given

$$H=\frac{p_y^2+p_y^2}{2\mu}+\frac{1}{2}\mu\omega^2\left(X^2+Y^2\right), \text{ then}$$

(1) $[L_x,H]=0$ (2) $[L_y,H]=0$ (3) $[L_z,H]=0$ (4) $[L_z,H]=1$

18. In hydrogen atom, the relation between potential energy V and kinetic energy T is:

(1) $\langle T\rangle = \langle V\rangle$ (2) $\langle T\rangle = -\langle V\rangle$ (3) $\langle T\rangle = \langle V\rangle/2$ (4) $\langle T\rangle = -\frac{1}{2}\langle V\rangle$

19. The correct relation for Pauli's spin matrices is

(1) $\sigma_x\sigma_y + \sigma_y\sigma_x = 2\mathbf{1}$ (2) $[\sigma_x, \sigma_y] = 2i\sigma_z$

(3) $T_r(\sigma_x\sigma_y) = 1$ (4) $T_r(\sigma_x^2) = 0$

20. A particle of mass m is in potential $V(x) = \lambda x^4$ using trial wave function

$$\Psi(x) = e^{-\frac{\alpha x^2}{2}}$$

The expectation value of energy is (α positive parameter)

(1) $\frac{\hbar^2\alpha}{m} + \frac{\lambda}{\alpha^2}$ (2) $\frac{\hbar^2\alpha}{4m} + \frac{\lambda}{\alpha^2}$ (3) $\frac{\hbar^2\alpha}{4m} + \frac{3\lambda}{4\alpha^2}$ (4) $\frac{\hbar^2\alpha}{4m} + \frac{3\lambda}{\alpha^2}$

21. For attractive delta potential $V = -aV_0\delta(x)$, the energy of bound state is (m is the mass of the particle)

(1) $\frac{-ma^2V_0^2}{2\hbar^2}$ (2) $\frac{-ma^2V_0^2}{\hbar^2}$ (3) $\frac{-ma^2V_0^2}{4\hbar^2}$ (4) $\frac{-ma^2V_0^2}{8\hbar^2}$

22. Consider the Hamiltonian of a particle

$$H = \frac{P^2}{2m} + \frac{1}{2}m\omega^2X^2 + qfX$$

Where q and f are constants. Treating the qfx term as perturbation the first order correction in the energy level is

(1) $\hbar\omega$ (2) $\frac{\hbar\omega}{2}$ (3) 0 (4) $-\frac{\hbar\omega}{2}$

23. The differential cross section for a particle of charge e on a potential $\frac{ze^2}{r}$ is (E is the kinetic energy)

(1) $\frac{(ze^2)^2}{16E^2\sin^4\left(\frac{\theta}{2}\right)}$ (2) $\frac{ze^2}{E^2\sin^4\left(\frac{\theta}{2}\right)}$

(3) $\frac{(ze^2)^2}{16E^2\sin^2\left(\frac{\theta}{2}\right)}$ (4) $\frac{(ze^2)^2}{16E^2\sin^4\theta}$

24. For harmonic oscillator (One dimensional) $\langle V \rangle = ?$

(1) $\hbar\omega\left(n+\frac{1}{2}\right)$ (2) $\frac{\hbar\omega}{2}\left(n+\frac{1}{2}\right)$ (3) $\hbar\omega$ (4) $\frac{\hbar\omega}{2}$

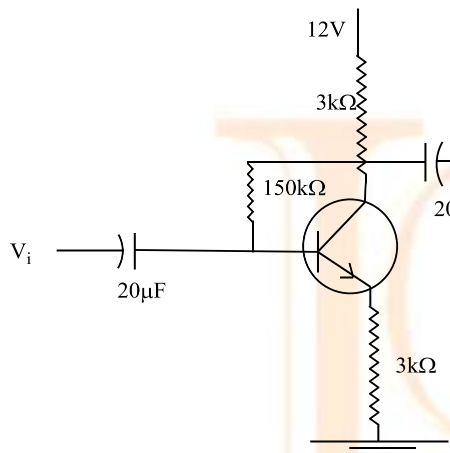
25. Consider the following operators on a Hilbert space

$$L_x = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}, L_z = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

Taking the state in which $L_z = 1$ the expectation value $\langle L_x \rangle$ in this state is

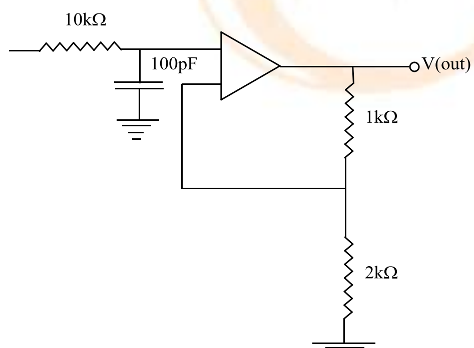
(1) 1 (2) -1 (3) 0 (4) $\frac{1}{\sqrt{2}}$

26. In the following circuit the value of collector current is $I_C = 1.49mA$. The current gain β_{DC} is



(1) 50 (2) 100 (3) 150 (4) 200

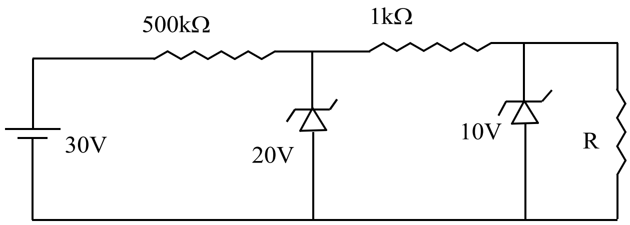
27. Consider the following circuit



For which frequency the closed loop gain is 1.5?

(1) $1.2kHz$ (2) $2.4kHz$ (3) $3.6kHz$ (4) $4.8kHz$

28. In the following circuit voltage and current across R are 10V and 5mA respectively the value of R is



(1) $8\,k\Omega$ (2) $6\,k\Omega$ (3) $4\,k\Omega$ (4) $2\,k\Omega$

29. The output voltage for a differential input of $200\ \mu V$ is 2V in a differential amplifier. The common mode gain is 0.1 dB then common mode rejection ratio (CMRR) is

(1) 50 dB (2) 100 dB (3) 150 dB (4) 200 dB

30. The power gain of an amplifier is 40 dB. For input of 1.5 W, the output power is

(1) 450 W (2) 300 W (3) 150 W (4) 75 W

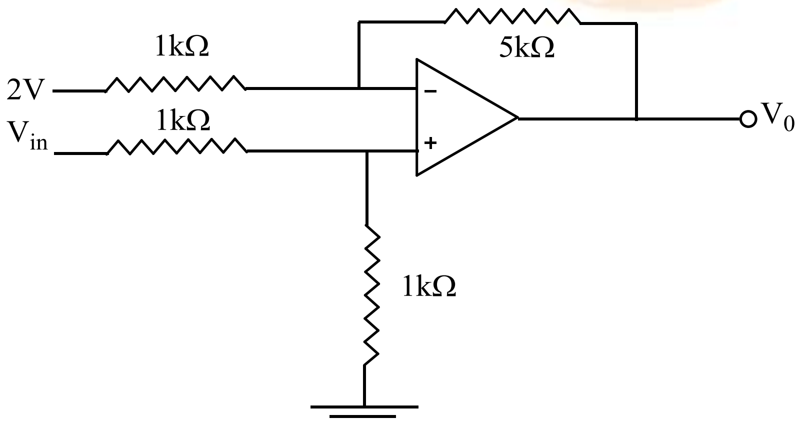
31. An AC voltage V is applied to the primary of a 10:1 step down transformer. The secondary of the transformer is centre tapped and connected to a full wave rectifier with a load resistance the DC voltage appearing the load is $\frac{44}{\pi}$ volt, then the value of V(rms value) is:

(1) 240 V (2) 230 V (3) 220 V (4) 120 V

32. A field effect transistor is

(1) Unipolar device
(2) Special type of bipolar junction transistor
(3) Unijunction device
(4) Device with low input impedance

33. The output of the ideal op-amp circuit shown in the figure is -7V. The value of V_{in} is



(1) 4V (2) 3V (3) 2V (4) 1 V

34. The feedback ratio of an amplifier is -0.006. The voltage gain without feedback is -250. On application of a negative feedback, the voltage gain is

(1) 250 (2) -250 (3) 200 (4) -100

35. A photo diode is exposed to light with an illumination of $2.5\, mW/cm^2$. If the sensitivity of the diode for the given conditions is $37.4\, \mu A/\left(mW\ cm^2\right)$, the reverse current through the device is

(1) $187.0\mu A$ (2) $93.5\mu A$ (3) $41.5\mu A$ (4) $374\mu A$

36. The maximum collector current that a transistor can carry is 500 mA. If $\beta = 300$, the maximum allowable base current is

(1) $1.67mA$ (2) $1.67\mu A$ (3) $3.34mA$ (4) $3.34\mu A$

37. In transistor amplifier, the collector current swings from 2mA to 5mA as the base current changed from $5\mu A$ to $15\mu A$. The current gain is

(1) 100 (2) 200 (3) 300 (4) 150

38. An amplifier has an open loop voltage gain of 1, 00, 000, with negative voltage feedback; the voltage gain is reduced to 100. The sacrifice factor is

(1) 1000 (2) 100 (3) 5000 (4) 500

39. The drain current I_D in a JFET is given by

(1) $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ (2) $I_D = I_{DSS}\left(1 + \frac{V_{GS}}{V_P}\right)^2$

(3) $I_D = I_{DSS}\left(1 - \frac{V_P}{V_{GS}}\right)^2$ (4) $I_D = I_{DSS}\left(1 + \frac{V_P}{V_{GS}}\right)^2$

40. For a JFET $V_{GS(off)} = -4V$

The pinch of voltage is

(1) +2V (2) +8V (3) +4V (4) -4V

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Test – 3

Quantum Mechanics & Electronics

Answer Key

1.(1)	2.(1)	3.(2)	4.(3)	5.(1)	6.(4)	7.(1)	8.(4)	9.(2)	10.(2)
11.(2)	12.(3)	13.(1)	14.(2)	15.(2)	16.(1)	17.(3)	18.(4)	19.(2)	20.(3)
21.(1)	22.(3)	23.(1)	24.(2)	25.(3)	26.(2)	27.(1)	28.(4)	29.(2)	30.(3)
31.(3)	32.(1)	33.(4)	34.(4)	35.(2)	36.(1)	37.(3)	38.(1)	39.(1)	40.(3)