PAPER – III

PHYSICAL SCIENCES

Note : Attempt all the questions. Each question carries *two* (2) marks.

1. Using shift operator $\Delta^3 y_2$ is equal to

1) $\nabla^3 y_5$ 2) $\nabla^2 y_3$

3) $\nabla^5 y_3$ 4) 0

2. The christoffel's symbol of second kind $\begin{Bmatrix} i \\ ij \end{Bmatrix}$ is

1) $\partial / \partial x_j^i$ 2) $\partial / \partial x_i^j$

3) $\partial / \partial x^i (\log \sqrt{g})$ 4) $\partial / \partial x^i (\log g)$

3. The elements of translation group may be denoted positions four vectors x, μ translated for vector,

1) $x'_\mu = a_\mu - x_\mu$ 2) $x'_\mu = u_\mu a_\mu$

3) $x' = \dfrac{x_\mu}{a_\mu}$ 4) $x'_\mu = u_\mu + a_\mu$

4. Equation of motion for a pendulum bob suspended by a spring and allowed to swing in a vertical plane.

1) $mr^2\ddot{\theta} + 2mr\dot{r}\dot{\theta} + mgr\sin\theta = 0$ 2) $mr^2\ddot{\theta} + 2mr\dot{r}\dot{\theta} + mgr\cos\theta = 0$

3) $mr^2\ddot{\theta} + 2mr\dot{r}\dot{\theta} - mgr\cos\theta = 0$ 4) $mr^2\ddot{\theta} + 2mr\dot{r}\dot{\theta} - mgr\sin\theta = 0$

5. Which of the following relation is correct?

1) $\dfrac{\partial \dot{T}}{\partial \dot{q}_J} + 2\dfrac{\partial T}{\partial q_j} = Q_j$ 2) $\dfrac{\partial \dot{T}}{\partial \dot{q}_J} + \dfrac{\partial T}{\partial q_j} = Q_j$

3) $\dfrac{\partial \dot{T}}{\partial \dot{q}_J} - \dfrac{\partial T}{\partial q_j} = Q_j$ 4) $\dfrac{\partial \dot{T}}{\partial \dot{q}_J} - 2\dfrac{\partial T}{\partial q_j} = Q_j$

6. The path of shortest time between two points at different heights from ground is a part of

1) straight line 2) parabola

3) cycloid 4) circle

7. Find the value of α and β for the following canonical transformation equations

$Q = q^\alpha \cos \beta p$

$P = q^\alpha \sin \beta p$

1) $\dfrac{1}{2}$ and 2 2) 2 and $\dfrac{1}{2}$

3) 3 and 2 4) 2 and 3

8. Consider a particle of mass m moving in an one dimensional potential well with rigid walls at $x = -a$ and $x = a$, the quantization rule for this system based on WKB approximation is

1) $\int p(x) \cdot dx = 2\pi\hbar$ 2) $\int p(x) \cdot dx = 2n\pi\hbar$

3) $\int p(x) \cdot dx = 2n\pi^2\hbar^2$ 4) $\int p(x) \cdot dx = 4n\pi\hbar$.

9. Consider a spherically symmetric potential,

$$V(r) = \begin{cases} 0, & r > l \\ -V_0, & r < l \end{cases}$$

The differential scattering cross section of this potential using Born approximation is,

1) $\frac{4\mu^2 V_0^2}{q^6\hbar^4}\left|ql\cos ql - \sin ql\right|^2$ 2) $\frac{\mu^2 V_0^2}{q^6\hbar^4}\left|ql\cos ql - \sin ql\right|^2$

3) $\frac{2\mu^2 V_0^2}{q^2\hbar^4}\left|ql\cos ql - \sin ql\right|^2$ 4) $\frac{\mu^2 V_0^2}{q^2\hbar^4}\left|ql\cos ql - \sin ql\right|^2$

10. The relation for optical theorem for the elastic scattering of spherically symmetric potential is

1) $\sigma = \frac{4\pi^2}{k^2}\sum_{l=0}^{k}(2l+1)\sin^2\delta_l$ 2) $\sigma = \frac{\pi}{k}\sum_{l=0}^{k}(2l-1)\sin^2\delta_l$

3) $\sigma = \frac{4\pi}{k}\sum_{l=0}^{k}(2l+1)\sin^2\delta_l$ 4) $\sigma = \frac{\pi^2}{k^2}\sum_{l=0}^{k}(2l+1)\sin^2\delta_l$

11. Consider a mole of a material made of molecules for which the electron clouds each have l = 0, s = 1; there is no spin-orbit coupling. It is placed in an external magnetic field of strength 3 T, and is at a temperature of 2 K. What is the magnetic moment?

1) 5.46 J/T 2) 9.06 J/T

3) 6.82 J/T 4) 9.53 J/T

12. A collection N of non-interacting spins S_i, $i = 1, 2....N\left(S_i = \pm 1\right)$ is kept in an external magnetic field B at a temperature T. The Hamiltonian of the system is $H = -\mu B\sum_i S_i$. What should be the minimum value of $\frac{\mu B}{k_B T}$ for which the mean value $\left\langle S_i \right\rangle \geq \frac{1}{3}$?

1) $2\ln 2$ 2) $\ln 2$

3) $\frac{3}{2}\ln 2$ 4) $\frac{1}{2}\ln 2$

13. Which of the following is correct? The output impedance

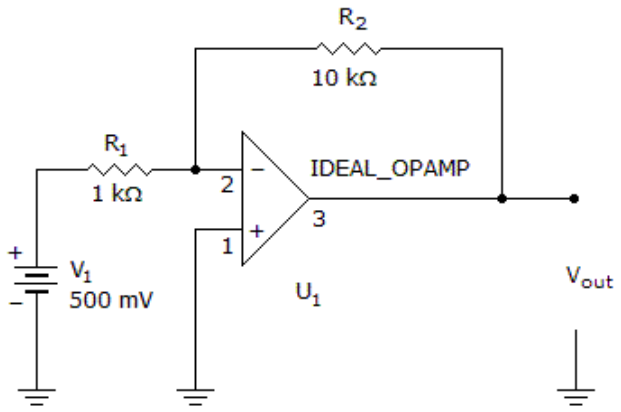
1) of a current source is high and voltage source is low

2) of a current source is low and voltage source is high

3) is high for both current and voltage source

4) is low for both current and voltage source

14. What is the output voltage of the following circuit?



1) 15 V

2) 5 V

3) –5 V

4) –15 V

15. The equivalent noise bandwidth of a network is

1) The bandwidth of the system

2) The bandwidth of the noise source

3) The bandwidth of a white noise

4) Combined bandwidth of source and white noises

16. F.T of $x(t)\cos(2\pi f_0 t)$ is

1) $x(t)\cos(2\pi f_0 t) \leftrightarrow 1/2\,X(f-f_0)+1/2\,X(f+f_0)$

2) $x(t)\cos(2\pi f_0 t) \leftrightarrow 1/2\,X(f-f_0)+2\,X(f+f_0)$

3) $x(t)\cos(2\pi f_0 t) \leftrightarrow X(f-f_0)+X(f+f_0)$

4) $x(t)\cos(2\pi f_0 t) \leftrightarrow 2\,X(f-f_0)+2\,X(f+f_0)$

17. With the increasing quantum number, the energy difference between adjacent levels in atom

1) increases

2) remains constant

3) decreases

4) becomes zero

18. When B is rotational constant in rotational Raman spectrum of CO molecule the separation between the Stokes line is

1) 2B
2) 4B
3) 6B
4) 12B

19. A transition between two rotational energy levels results in a radiation that falls in the,

1) Visible or ultra violet region
2) Near infra-red region or microwave region
3) Far infra-red region or microwave region
4) All the above

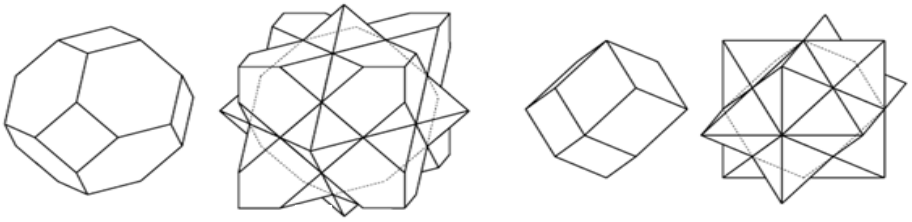
20. Identify from the following the volume of the rhombohedral unit cell

1) $abc\sqrt{1-\cos^2\alpha-\cos^2\beta-\cos^2\gamma+2\cos\alpha\cos\beta\cos\gamma}$
2) $abc\sin\beta$
3) abc
4) $a^3\sqrt{1-3\cos^2\alpha+2\cos^3\alpha}$

21. How many Rhombohedral unit cells makes one Hexagonal unit cell?

1) 2
2) 3
3) 4
4) 6

22. Identify the external first Brillouin zone boundary of the FCC system from the following surfaces



(A) (B) (C) (D)

1) (A)
2) (B)
3) (C)
4) (D)

23. The inverse Fourier transform of structure factor F_G will result in

1) Ist Brillouin zone
2) IInd brillouin zone
3) Charge density
4) Fermi surface

24. If the velocity of sound in a mono-atomic solid is of the order 10^3 m/s, the frequency of the sound wave whose λ = 20 Å is

1) $\omega = 3.14 \times 10^{12} rad/\sec$ 2) $\omega = 6.28 \times 10^{12} rad/\sec$

3) $\omega = 3.14\, rad/\sec$ 4) $\omega = 6.28\ rad/\sec$

25. Which of the following represents Debye T^3 law?

1) $C_v \cong \frac{12\pi^3}{3} Nk_B \left(\frac{T}{\theta}\right)^3$ 2) $C_v \cong \frac{\pi^3}{5} Nk_B \left(\frac{T}{\theta}\right)^3$

3) $C_v \cong \frac{12\pi^4}{5} Nk_B \left(\frac{T}{\theta}\right)^3$ 4) $C_v \cong \frac{\pi^4}{5} Nk_B \left(\frac{T}{\theta}\right)^3$

26. Thermo electric generator works with the principle of

1) Peltier effect 2) Joule-Thomson effect

3) Seebeck effect 4) Debye–Falkenhagen effect

27. For which type of material is the Fermi energy level is located in the gap between valence and conduction bands?

1) conductor only 2) semiconductor only

3) conductor and semiconductor 4) insulator and semiconductor

28. The size of the nucleus can be determined by

1) Electron scattering

2) Energy levels of muonic atoms

3) Ground state energies of the isotopic spin multiplet

4) All of the above

29. The binding energy per nucleon is maximum for the nucleus

1) ^{56}Fe 2) ^{4}He

3) ^{208}Pb 4) ^{236}U

30. Binding fraction of deuteron is

1) –2.2244 MeV 2) 2.013553 u

3) –1.1122 MeV 4) 1.008665 u

31. Identify the unknown X in the reaction ${}^{6}Li(d, \alpha)X$

1) ${}^{4}Be$ 2) ${}^{4}Li$

3) ${}^{4}He$ 4) ${}^{4}H$

32. The reaction which led to the discovery of first artificial radioactive isotope by Irene Curie is

1) ${}^{27}Al(\alpha, n)^{30}P$ 2) ${}^{27}Al(p, n)^{30}P$

3) ${}^{27}Al(p, \alpha)^{30}P$ 4) ${}^{27}Al(n, \alpha)^{30}P$

33. Which of the following is spallation reaction?

1) Radioactive decay 2) Nuclear fission

3) Nuclear fusion 4) Inelastic scattering

34. The reaction $\pi^{-} + p \rightarrow \Lambda^{\circ} + \pi^{\circ}$ is forbidden because of

1) Law of baryon number conservation 2) Law of strangeness conservation

3) Law of charge conservation 4) Law of hypercharge conservation

35. The baryon number of proton, the lepton number of proton, the baryon number of lepton and the lepton number of electron are respectively

1) Zero, zero, one and zero 2) One, one, zero and one

3) One, zero, zero and one 4) Zero, one, one and zero

36. A state containing only one strange particle

1) Can decay into a state of zero strangeness

2) Can be created strongly from a state of zero strangeness

3) Cannot exist

4) Cannot decay

37. The charge of charm, down, top quarks are respectively

1) $\left(\frac{2}{3}e\right), \left(\frac{-1}{3}e\right), \left(\frac{-1}{3}e\right)$ 2) $\left(\frac{2}{3}e\right), \left(\frac{-1}{3}e\right), \left(\frac{2}{3}e\right)$

3) $\left(\frac{1}{3}e\right), \left(\frac{-1}{3}e\right), \left(\frac{2}{3}e\right)$ 4) $\left(\frac{2}{3}e\right), \left(\frac{2}{3}e\right), \left(\frac{-1}{3}e\right)$

38. Greens functions for the boundary value problem $\frac{d^2y}{dx^2} + \mu^2 x = 0$ with boundary condition $y(0) = 0 = y(1)$ when $x < t$

1) $-\frac{\sin \mu x \sin \mu(t-1)}{\mu \sin \mu}$

2) $-\frac{\sin \mu t \sin \mu(x-1)}{\mu \sin \mu}$

3) $\frac{\sin \mu x \sin \mu(t-1)}{\mu \sin \mu}$

4) $\frac{\sin \mu t \sin \mu(x-1)}{\mu \sin \mu}$

39. Diffusivity of the substance h^2 in two dimensional steady flow of heat is given by

1) $h^2 = \nabla^2 \psi$

2) $\frac{\partial \psi}{\partial t} = h^2 \nabla^2 \psi$

3) $\frac{\partial \psi}{\partial t} = h^2$

4) $\nabla \psi = h^2$

40. A string stretched between two fixed points (0,0) ad (1,0) and is released at rest from the positions $u = \lambda \sin \pi x$. The expression for its subsequent displacement $u(x,t)$ is,

1) $\lambda \cos(c\pi t) \sin(\pi x)$

2) $\lambda \sin(c\pi t) \sin(\pi x)$

3) $\lambda \cos(\pi t) \sin(c\pi x)$

4) $\lambda \sin(c\pi t) \cos(\pi x)$

41. In Simpson's rule if fourth derivation exist and is continues on $a \le x \le b$ then the error is

1) $\frac{(b-a)}{180} h^4 f^{(4)}(t)$

2) $(b-a) h^4 f^{(4)}(t)$

3) $\frac{-(b-a)}{180} h^4 f^{(4)}(t)$

4) $-(b-a) h^4 f^{(4)}(t)$

42. The Runge - Kutta formula of the fourth order for the solution of the equation $\frac{dy}{dx} = f(x),\ y(x_0) = y_0$ reduces to

1) Euler's formula

2) Simpson's Rule of Integrals

3) Picards Formula

4) Taylor Series

43. The wave velocity of the rectangular waveguide is

1) $\frac{2\pi c}{\sqrt{1-\frac{\omega_{mn}}{\omega}}}$

2) $\frac{c}{\sqrt{1-\frac{\omega_{mn}}{\omega}}}$

3) $c\sqrt{1-\left(\frac{\omega_{mn}}{\omega}\right)^2}$

4) $\frac{c}{\sqrt{1-\left(\frac{\omega_{mn}}{\omega}\right)^2}}$

44. The dispersion of EM waves in plasma is

1) $\sqrt{\omega_p^2+(ck)^2}$

2) $\sqrt{\omega_p+(ck)}$

3) $\sqrt{\omega_p^2+(ck)}$

4) $\sqrt{\omega_p+(ck)^2}$

45. Radiation power from a oscillating dipole is given by

1) $P=\frac{2\pi}{3}\sqrt{\frac{\mu_o}{\varepsilon_o}}\left(\frac{l}{\lambda}\right)^2\frac{I_o^2}{2}$

2) $P=\frac{2\pi}{3}\sqrt{\frac{\mu_o}{\varepsilon_o}}\left(\frac{l}{\lambda}\right)^2\frac{I_o}{2}$

3) $P=\frac{2\pi}{3}\sqrt{\frac{\mu_o}{\varepsilon_o}}\left(\frac{l}{\lambda}\right)\frac{I_o^2}{2}$

4) $P=\frac{2\pi}{3}\sqrt{\frac{\mu_o}{\varepsilon_o}}\left(\frac{\lambda}{l}\right)^2\frac{I_o^2}{2}$

46. A classical charged particle moving with frequency ω in a circular orbit of radius 'a' centered at origin in the *x-y* plane, emits electromagnetic radiation. At points (*b*, 0, 0) and (0, 0, *b*) where b>>a, the electromagnetic waves are,

1) circularly polarized and elliptically polarized respectively

2) plane polarized and elliptically polarized respectively

3) plane polarized and circularly polarized respectively

4) circularly polarized and plane polarized respectively

47. The spin orbit energy is a consequence of

1) Klein-Gordan equation

2) Dirac equation

3) Hamilton equation

4) Radial equation

48. Which of the following equations gives spin-orbit coupling energy as a result?

1) $[c\vec{\alpha}\cdot p+\beta mc^2]\psi=E\psi$

2) $[c\vec{\alpha}\cdot p+\beta mc^2+V(r)]\psi=E\psi$

3) $[c\vec{\alpha}\cdot p+\beta mc^2+V(r)]\psi=0$

4) $[c\vec{\alpha}\cdot p+V(r)]\psi=E\psi$

49. A Carnot engine uses a paramagnetic substance as its working substance. The equation of state is $M = \frac{nDH}{T}$ where M is magnetization, H is the magnetic field, n is the number of moles, D is a constant determined by the type of substance, and T is the temperature. The efficiency of the Carnot engine is

1) $\frac{T_c}{T_h}$ 2) $\frac{T_h - T_c}{T_h}$

3) $\frac{T_h - 2T_c}{T_h}$ 4) $\frac{T_c^2 - T_h}{T_h}$

50. For water vapour, $u_0 = 0$. Each molecule has six degrees of freedom in both the vapour and liquid phases. The latent heat of vaporization for water is 40700 J/mole and as it vaporizes, it expands. The average work done per molecule in this expansion is $pv = kT$. The specific heat of liquid water is 75.3 J/(mole K). The molar mass of water is 18 g/mole. Use this information to calculate the average energy of a water molecule (in eV) for water vapor at 100°C

1) 0.096 eV 2) 1 eV

3) 0.5 eV 4) 0.7 eV

51. Imagine an organism that lives in a hydrothermal vent where the temperature is 80°C and the salinity is 4% by number of ions. If the organism's body fluids have a salinity of 1%, what is the osmotic pressure across in membranes separating this organism's body fluids from its environment?

1) 4.9×10^6 Pa 2) 9.4×10^6 Pa

3) 3.5×10^6 Pa 4) 4.9×10^2 Pa

52. Identify, which one of the following can act as an inverse transducer

1) Electrical resistance potentiometer 2) LVDT

3) Capacitive transducer 4) Piezoelectric crystals

53. The temperature transducers exhibit nonlinear behavior; the order of nonlinearity (highest to lowest) is

1) Thermocouples, RTD, Thermistors 2) Thermistors, Thermocouples, RTD

3) RTD, Thermocouples, Thermistors 4) Thermistors, RTD, Thermocouples

54. In an LVDT, the core is made up of a

1) non-magnetic material

2) a solid ferro-electric material

3) high permeability, nickel-iron hydrogen annealed material in order to Produce low harmonics, low null voltage & high sensitivity

4) non-magnetic material with low permeability

55. A transition between two electronic levels results in a radiation that falls in the,

1) Infra-red and visible region
2) Visible or ultra violet region
3) Microwave region
4) All the above

56. A three level laser system has $E_1 = 0\ eV$ and $E_2 = 1\ eV$, $E_3 = 3\ eV$ and $A_{32} = 7 \times 10^7\ s^{-1}$, $A_{31} = 10^7\ S^{-1}$, $A_{21} = 10^8\ s^{-1}$. The spontaneous lifetime of level 3 is.

1) $1.5 \times 10^{-7}\ s$
2) $1.09 \times 10^{-8}\ s$
3) $0.25 \times 10^{-8}\ s$
4) $1.25 \times 10^{-8}\ s$

57. If the rotational constant of a molecule in the upper and lower vibrational states are considered equal, the band head is observed in

1) P-branch
2) Q-branch
3) R-branch
4) Not observed

58. The pure rotational bands arise due to the transition between

1) Same electronic and vibrational levels
2) Different electronic and vibrational levels
3) Same electronic levels only
4) Same vibrational levels only

59. Which of the following molecules will show Raman spectra?

1) N_2
2) HCl
3) O_2
4) All the above

60. When J and K represents the total angular momentum and its projection along the symmetry axis of a rigid symmetric top molecule, the selection rule for the rotational transitions are

1) $\Delta J = +1,\ \Delta K = 0$
2) $\Delta J = -1,\ \Delta K = 0$
3) $\Delta J = \pm 1,\ \Delta K = 0$
4) $\Delta J = \pm 1,\ \Delta K = \pm 1$

61. Which of the molecule show rotational spectrum?

1) H_2
2) O_2
3) $^{16}O - {}^{17}O$
4) CO

62. Rotational Raman selection rule $\Delta J = \pm 2$ is due to which of the following

1) Polarizability ellipsoid is unsymmetrical
2) Polarizability ellipsoid is 2 fold symmetric
3) Polarizability ellipsoid is 3 fold symmetric
4) Polarizability ellipsoid is 4 fold symmetric

63. The de Broglie wavelength associated with an electron of mass m and accelerated by a potential V is

1) $\frac{h}{\sqrt{2meV}}$ 2) $\frac{\sqrt{2meV}}{h}$

3) $\frac{h}{2meV}$ 4) $\frac{2meV}{h}$

64. The energy of X-ray photon is about 8.2 keV. The wavelength is

1) 1.512 Å 2) 1.5414 Å

3) 1.712 Å 4) 0.812 Å

65. The ratio between the amplitude scattered by an atom to the amplitude scattered by an electron is called

1) structure factor 2) phase factor

3) atomic scattering factor 4) intensity of scattering

66. In a mono-atomic cubic crystal, the distance between the two neighboring atoms is $\frac{\sqrt{3}a}{4}$, then the crystal is belongs to what type of cubic system?

1) Simple cubic 2) BCC

3) FCC 4) Diamond cubic

67. The effective mass of a Bloch electron is defined as

1) $\frac{1}{m^*} = \frac{1\partial^2 \in_K}{\hbar^2 \partial K^2}$ 2) $\left(\frac{1}{m^*}\right)^2 = \frac{1\partial^2 \in_K}{\hbar^2 \partial K^2}$

3) $\frac{1}{m^*} = \left[\frac{1\partial^2 \in_K}{\hbar^2 \partial K^2}\right]^2$ 4) $\frac{1}{m^*} = \left[\frac{1\partial^2 \in_K}{\hbar^2 \partial K^2}\right]^{1/2}$

68. When more number of phonons participate in the collision at high temperatures

1) It reduces mean free path and hence conductivity

2) It increases mean free path and hence conductivity

3) It reduces mean free path but conductivity increases

4) It increases mean free path but reduces conductivity

69. The non-zero quadrupole moment of deuteron indicates, that the g_s of deuteron is

1) A mixture of the triplet state $^3S_1$ and the singlet state $^1S_1$

2) A mixture of the triplet state $^3S_1$ and $^3D_1$

3) Triplet state $^3S_1$

4) Triplet state $^3D_1$

70. The shell model scheme of ^{11}B, with proton and neutron levels respectively is,

1) $(1s_{1/2})^2(1p_{3/2})^3;(1s_{1/2})^2(1p_{3/2})^4$

2) $(1s_{1/2})^2(1p_{3/2})^4;(1s_{1/2})^2(1p_{3/2})^3$

3) $(1s_{1/2})^2(1p_{3/2})^4;(1s_{1/2})^2(1d_{3/2})^3$

4) $(1s_{1/2})^2(1p_{3/2})^3;(1s_{1/2})^2(1d_{3/2})^4$

71. The half-life of ^{259}Fm is 1.5s. The decay constant is

1) $10.462\ s^{-1}$

2) $15.462\ s^{-1}$

3) $0.462\ s^{-1}$

4) $1.462\ s^{-1}$

72. The existence of the neutrino was postulated in order to explain

1) α decay

2) γ emission

3) fission

4) β decay

73. The decay constant of ^{90}Sr is $7.83\times10^{-10}\ s^{-1}$. The half-life is

1) 83×10^{-10} sec

2) 28 years

3) 678 min

4) 45 hours

74. How much energy in MeV would have to be supplied to a nucleus of $^{236}_{92}U$ in order to split it into two identical fragments $^{118}_{46}Pd$. The mass of $^{236}_{92}U$ is 236.045568 u and the mass of $^{118}_{46}Pd$ is 117.91906 u

1) 193 MeV

2) 236 MeV

3) 118 MeV

4) 100 MeV

75. If the mass of the reactants is larger than the mass of the products, the reaction is said to be

1) Exoergic reaction

2) Endoergic reaction

3) Elastic scattering

4) None of these

ROUGH WORK

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