ALL INDIA TEST SERIES

FOR

CSIR/NET-JRF (PHYSICS) June-2026

Full Length Test

PHYSICAL SCIENCES

TIME: 3 HOURS **MAXIMUM MARKS: 200**

Part 'A' This part shall carry 20 questions pertaining to *General Aptitude with emphasis, On logical reasoning, graphical, analysis, analytical and numerical ability, quantitative comparison, series formation, puzzles etc.* The candidates shall be required to answer any 15 questions. Each question shall be of two marks. The total marks allocated to this section shall be 30 out of 200.

Part 'B' This part shall contain 25 Multiple Choice Questions (MCQs) generally covering the topics given in the Part 'A' (CORE) of syllabus. All questions are compulsory. Each question shall be of 3.5 Marks. The total marks allocated to this section shall be 70 out of 200.

Part 'C' This part shall contain 30 questions from Part 'B'(Advanced) that are designed to test a candidate's knowledge of scientific concepts and/or application of the scientific concepts. The questions shall be of analytical nature where a candidate is expected to apply the scientific knowledge to arrive at the solution to the given scientific problem. A candidate shall be required to answer any 20. Each question shall be of 5 Marks. The total marks allocated to this section shall be 100 out of 200.

There will be negative marking @25% for each wrong answer.

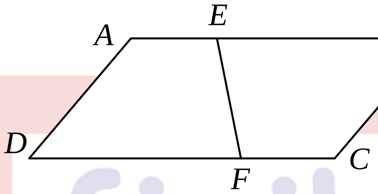
PART A

ANSWER ANY 15 QUESTONS

Q1. A four digit number is divisible by 9. Exactly three consecutive digits of this number are the same. How many such numbers are there?

(a) 12 (b) 16 (c) 19 (d) 20

Q2. $ABCD$ is a parallelogram such that AB is parallel to DC and DA is parallel to CB.



The length of side AB is $20\ cm$. E is a point between A and B such that the length $AE = 3\ cm$. F is a point between D and C.

If the line segment EF divides the parallelogram in two parts of equal area then the length DF is

(a) $15 cm$ (b) $17 cm$ (c) $20 cm$ (d) $24 cm$

Q3. Find the missing number (?) in the figure shown

6	5	72
7	4	76
8	2	?

(a) 73 (b) 77 (c) 78 (d) 79

Q4. A, B, C, D, E, F and G live in different floors of the same building. D lives between B and F. E and A live on successive floors. B lives on top floor. There is exactly one person between C and E. There are exactly two persons between F and G.

How many persons live between G and A?

(a) 1 (b) 2 (c) 3 (d) 4

Q5. How many 6 digit telephone numbers can be formed if each number starts with 35 and no digits appears more than once?

(a) 720 (b) 360 (c) 1420 (d) 1680

Q6. The profit earned by selling a watch for Rs. $18,000$ is the same as the loss incurred if the watch is sold for Rs. $16,800$. The price at which the watch should be sold to make a profit of 25% is

(a) Rs. $16,400$ (b) Rs. $21,750$ (c) Rs. $23,400$ (d) Rs. $25,750$

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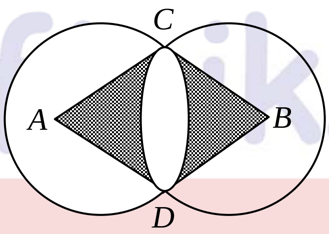
Q7. A leap year has 366 days. The probability that a leap years has exactly 52 Sundays is

(a) $\frac{2}{7}$ (b) $\frac{3}{7}$ (c) $\frac{4}{7}$ (d) $\frac{5}{7}$

Q8. The ratio of students in three classes of a school is $2:3:5$. If 20 students in each class are increased then this ratio becomes $4:5:7$. The total number of students in the three classes before the increase was

(a) 50 (b) 100 (c) 150 (d) 200

Q9. In the diagram shown, A and B are the centers of the two circles, each with radius $6\,cm$ and $\angle A = \angle B = 60^0$. The area (in cm^2) of the shaded region is



(a) $12\pi - 18\sqrt{3}$ (b) $18\sqrt{3} - 6\pi$

(c) $36\sqrt{3} - 12\pi$ (d) $24\pi - 18\sqrt{3}$

Q10. A and B walk around a circular track. A and B walk at a speed of 2 rounds per hour and 3 rounds per hour respectively. If they start at $8\ AM$ from the same point in opposite directions, how many times shall they cross each other before $9:30\ AM$?

(a) 6 (b) 7 (c) 8 (d) 9

Q11. If every second Saturday and every Sunday in a year is a holiday and there are no other holidays, then how many working days will be there in a leap year that begins with Friday?

(a) 285 (b) 286 (c) 287 (d) 288

Q12. How many times in a day, are the hands of a clock in straight line but in opposite in direction?

(a) 20 (b) 22 (c) 24 (d) 48

Q13. There are two bars of copper-nicked alloy. One bar has 2 parts of copper to 5 parts of nickel. The other has 3 parts of copper to 5 parts of nickel. If both bars are melted together to get a $20\ kg$ bar with final copper to nickel ratio of $5:11$, the weight of first bar is

(a) $12\,kg$ (b) $13\,kg$ (c) $14\,kg$ (d) $16\,kg$

Q14. How many different positive integers exists between 10^6 and 10^7, the sum of whose digits is equal to 2?

(a) 6 (b) 7 (c) 8 (d) 9

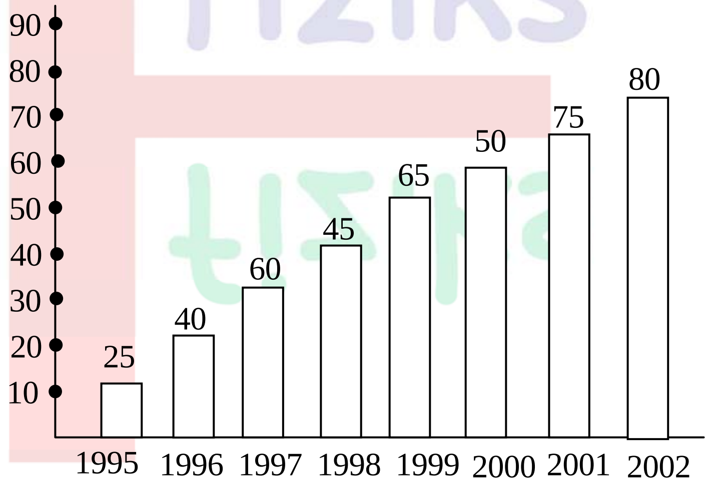
Q15. In a class of 5 students , average weight of 4 lightest students is $40\ kg$. Average weight of 4 heaviest students is $45\,kg$. The difference between maximum possible average weight and the minimum possible average weight of the class is

(a) $3\,kg$ (b) $4\,kg$ (c) $5\,kg$ (d) $6\,kg$

Q16. A $5\,cm$ cube is cut into as many $1\,cm$ cubes as possible. The ratio of surface areas of the larger cube to the sum of surface areas of smaller cubes is

(a) $1:6$ (b) $1:5$ (c) $1:25$ (d) $1:125$

Q17.



The production of fertilizes by a company (in 1000 tones) over the years is shown in the above bar chart. The percentage increase in production as compared to the previous year was maximum in the year

(a) 2001 (b) 2002 (c) 1997 (d) 1996

Q18. A stone is thrown upward from the surface of the earth with a speed of $98\,m/s$. At the same time another stone is dropped from a tower of height $500\,m$. After 4 seconds the relative speed of stones is (acceleration due to gravity $= 9\cdot 8\,m/s^2$)

(a) $40\,m/s$ (b) $49\,m/s$ (c) $98\,m/s$ (d) $80\,m/s$

Q19. Which of the figures given below best depicts the relationship among Books, Dictionaries and Printers.

(a) P (b) Q (c) R (d) S

Q20. Point G is $9m$ east of H which is $18m$ north of point I. Point A is $10m$ south of point J. Point F is $21m$ south of point G. Point C is $4m$ west of point D. Point E is $7m$ west of point F. Point C is $5m$ south of point B and D is $6m$ north of point E. Point A is $4m$ east of point E.

The shortest distance between point D and I is

(a) $\sqrt{7}m$ (b) $\sqrt{10}m$ (c) $\sqrt{12}m$ (d) $\sqrt{13}m$

PART B

ANSWER ANY 20 QUESTONS

Q21. Consider an electromagnetic wave at the interface between two homogenous dielectric media of dielectric constants ε_1 and ε_2. Assuming $\varepsilon_2 < \varepsilon_1$ and no charges on the surface, the electric field vector $\vec{E}$ and the displacement vector $\vec{D}$ in the two media satisfy the following inequalities

(a) $|\vec{E}_2| > |\vec{E}_1|$ and $|\vec{D}_2| > |\vec{D}_1|$ (b) $|\vec{E}_2| < |\vec{E}_1|$ and $|\vec{D}_2| < |\vec{D}_1|$

(c) $|\vec{E}_2| < |\vec{E}_1|$ and $|\vec{D}_2| > |\vec{D}_1|$ (d) $|\vec{E}_2| > |\vec{E}_1|$ and $|\vec{D}_2| < |\vec{D}_1|$

Q22. For the canonical ensemble if $\Delta E = \left(\langle E^2 \rangle - \langle E \rangle^2\right)^{1/2}$ is the error in measurement of energy E, then constant volume heat capacity C_V is given by.

(a) $\frac{1}{kT^2}\langle E \rangle^2$ (b) $\frac{1}{kT^2}\langle E^2 \rangle$ (c) $\frac{1}{kT^2}(\Delta E)^2$ (d) $\frac{1}{kT^2}(\langle E^2 \rangle + \langle E \rangle^2)$

Q23. Consider the equation $\frac{dy}{dx} = \frac{y^2}{x}$ with the boundary condition $y(1) = 1$. Then the solution y will blow up as x tends to

(a) 0 (b) $1/2$ (c) 1 (d) ∞

Q24. A system is governed by the Hamiltonian $H = \frac{1}{2}(p_x + ax)^2$ and a physical quantity is given by $A = (p_x - bx)$, where a and b are constants and p_x is momentum conjugate to x. The ratio between a and b for which the quantity $A = (p_x - bx)$ is conserved is given by

(a) $\frac{b}{a} = 1$ (b) $\frac{b}{a} = -1$ (c) $\frac{b}{a} = 2$ (d) $\frac{b}{a} = -2$

Q25. A long straight wire of radius $'a'$ caries a steady current i. The current is uniformly district across its cross section. The ratio of the magnetic field at $\frac{a}{2}$ and $2a$ is

(a) 1 (b) 2 (c) 3 (d) 4

Q26. The normalized wavefunction of a particle in three dimensions is given by $\psi(r,\theta,\varphi)=\frac{1}{\sqrt{8\pi a^3}}e^{-r/2a}$ where $a>0$ is a constant. The ratio of the square of most probable distance from the origin to the mean square distance from the origin, is

[You may use $\int_0^\infty dx\, x^n e^{-x} = n!$]

(a) $\frac{1}{4}$ (b) $\frac{1}{3}$ (c) $\frac{1}{2}$ (d) $\frac{2}{3}$

Q27. The value of integral

$$I=\oint_c \frac{\sin z}{2z-\pi}dz$$

with c a circle $|z|=2$, is

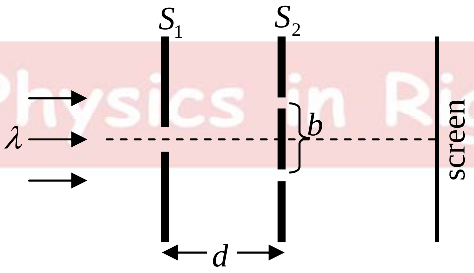
(a) 0 (b) $2\pi i$ (c) πi (d) $-\pi i$

Q28. The periodic quantity S is function of position $\vec{r}_\alpha$ and corresponding momentum $\vec{p}_\alpha$ defined as $S=\sum_\alpha \vec{p}_\alpha.\vec{r}_\alpha$. If $\vec{F}_\alpha$ is generalized force and T is kinetic energy of system then which of the following is correct?

(a) $\langle T\rangle = \frac{1}{2}\left\langle \sum_\alpha \vec{F}_\alpha.\vec{r}_\alpha \right\rangle$ (b) $\langle T\rangle = -\frac{1}{2}\left\langle \sum_\alpha \vec{F}_\alpha.\vec{r}_\alpha \right\rangle$

(c) $\langle T\rangle = 2\left\langle \sum_\alpha \vec{F}_\alpha.\vec{r}_\alpha \right\rangle$ (d) $\langle T\rangle = -2\left\langle \sum_\alpha \vec{F}_\alpha.\vec{r}_\alpha \right\rangle$

Q29. The figure describes the arrangement of slits and screens in a Young's double slit experiment. The width of the slit in S_1 is a and the slits in S_2 are of negligible width. If the wavelength of the light is λ, the value of d for which the screen would be dark is



(a) $b\sqrt{\left(\frac{a}{\lambda}\right)^2-1}$ (b) $\frac{b}{2}\sqrt{\left(\frac{a}{\lambda}\right)^2-1}$ (c) $\frac{a}{2}\left(\frac{b}{\lambda}\right)^2$ (d) $\frac{ab}{\lambda}$

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Q30. If the plot between Helmholtz free energy per particle of one dimensional harmonic oscillator with frequency ω at temperature T is as shows in the figure then the value of α is given by

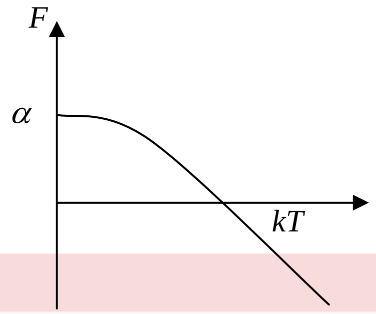


Figure: Plot of F verses kT

(a) $\frac{\hbar\omega}{2}$ (b) $\hbar\omega$ (c) $\frac{3\hbar\omega}{2}$ (d) $2\hbar\omega$

Q31. For Dirac particle if x component of angular momentum is given by $L_z = xp_y - yp_x$ then the value of $\frac{dL_z}{dt}$ is

(a) $c\left[p_y\alpha_x - p_x\alpha_y\right]$

(b) $c\left(p_z\alpha_y - p_y\alpha_z\right)$

(c) $c\left(p_y\alpha_y - p_z\alpha_z\right)$

(d) $c\left(p_y\alpha_z - p_z\alpha_y\right)$

Q32. A laser sinusoidal electric field of amplitude E_0 $\left(V/m\right)$ and frequency f_0. Starting from an arbitrary initial time, the waveform is sampled at intervals of $\frac{1}{2f_0}$. If the corresponding Fourier spectrum peaks at a frequency $\bar{f}$ and an amplitude $\bar{A}$, then

(a) $\bar{f} = 2f_0$ and $\bar{A} = E_0$

(b) $\bar{f} = f_0$ and $0 \le \bar{A} \le E_0$

(c) $\bar{f} = 0$ and $\bar{A} = E_0$

(d) $\bar{f} = \frac{f_0}{2}$ and $\bar{A} = \frac{1}{\sqrt{2}}E_0$

Q33. The wave number k and the angular frequency ω of a wave are related by the dispersion relation $\omega^2 = \beta k + \alpha k^3$ where α and β are positive constants. The wave number for which the phase velocity equals the group velocity, is

(a) $3\sqrt{\frac{\alpha}{\beta}}$ (b) $\sqrt{\frac{\alpha}{\beta}}$ (c) $\sqrt{\frac{\beta}{\alpha}}$ (d) $\frac{1}{3}\sqrt{\frac{\alpha}{\beta}}$

Q34. Infinite charge sheet with density σ is kept in x, y plane. If the sheet is moving with speed v with respect to observer in positive x direction. Which of the following is correct expression of electric field and magnetic field at distance a in $\hat{z}$ direction. $\left(\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right)$?

(a) $E_z = \frac{\gamma\sigma}{\varepsilon_0}, B_z = -\frac{\gamma v\sigma}{\varepsilon_0 c^2}$

(b) $E_z = \frac{\gamma\sigma}{\varepsilon_0}, B_y = -\frac{\gamma v\sigma}{\varepsilon_0 c^2}$

(c) $E_y = \frac{\gamma\sigma}{\varepsilon_0}, B_z = -\frac{\gamma v\sigma}{\varepsilon_0 c^2}$

(d) $E_z = \frac{\gamma\sigma}{\varepsilon_0}, B_y = \frac{\gamma v\sigma}{\varepsilon_0 c^2}$

Q35. Consider a one-dimensional infinite square well

$$V(x) = \begin{cases} 0 & \text{for } 0 < x < a, \\ \infty & \text{otherwise} \end{cases}$$

If a perturbation

$$H_p(x) = \begin{cases} V_0 & \text{for } 0 < x < a/4, \\ 0 & \text{otherwise} \end{cases}$$

is applied, then the correction to the energy of the first excited state, to first order in ΔV, is nearest to

(a) V_0 (b) $0.16\, V_0$ (c) $0.25\, V_0$ (d) $0.33\, V_0$

Q36. If generating function is given by $F(q,Q) = \frac{1}{2}\omega q^2 \cot 2\pi Q$ then which one of the following is correctly matched?

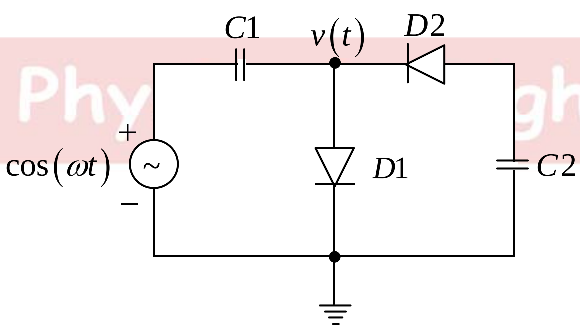
(a) $\frac{q}{p} = \frac{1}{\omega}\tan 2\pi Q$

(b) $\frac{q}{p} = \frac{1}{\omega}\cot 2\pi Q$

(c) $\frac{q}{p} = \omega \tan 2\pi Q$

(d) $\frac{q}{p} = \omega \cot 2\pi Q$

Q37. The diodes and capacitor in the circuit shown are ideal. The voltage $v(t)$ across the diode $D1$ is



(a) $\cos(\omega t) - 1$ (b) $\sin(\omega t)$ (c) $\cos(\omega t)$ (d) $1 - \sin(\omega t)$

Q38. If particle of mass m having energy E is scattered with for potential $V(r)=V_0\delta(r-a)$ the relation between phase shift δ_0 and energy $k=\sqrt{\frac{2mE}{\hbar^2}}$ is given by $\tan(ka+\delta_0)=\left[\frac{1}{\tan(ka)}+\frac{2mV_0}{k\hbar^2}\right]^{-1}$ then total scattering cross section for low energy is given by

(a) $4\pi a^2$

(b) $\frac{4\pi a^2}{k^2a^2+\left(1+2mV_0a/\hbar^2\right)^2}$

(c) $\frac{4\pi a^2}{\left(1-2mV_0a/\hbar^2\right)^2}$

(d) $\frac{4\pi a^2}{\left(1+2mV_0a/\hbar^2\right)^2}$

Q39. The Fourier transform of $f(x)$ is $\tilde{f}(k)=\frac{1}{\sqrt{2}}\int_{-\infty}^{+\infty}dxe^{ikx}f(x)$.

If $f(x)=\alpha\delta(x)+\beta\delta'(x)+\gamma\delta''(x)$, where $\delta(x)$ is the Dirac delta-function (and prime denotes derivative), what is $\tilde{f}(k)$?

(a) $\alpha+i\beta k+i\gamma k^2$

(b) $\alpha+\beta k-\gamma k^2$

(c) $\left(\frac{1}{\sqrt{2}}\right)\alpha-i\beta k-\gamma k^2$

(d) $\frac{1}{\sqrt{2}}\left(i\alpha+\beta k-i\gamma k^2\right)$

Q40. An ideal gas is confined into a box of volume V. If U is internal energy of system at equilibrium temperature then partition function of the system is given by

(a) $Z=\left(\frac{\pi mU}{h^2N}\right)^{3N/2}\frac{V^N}{\lfloor N}$

(b) $Z=\left(\frac{\pi mU}{3h^2N}\right)^{3N/2}\frac{V^N}{\lfloor N}$

(c) $Z=\left(\frac{2\pi mU}{3h^2N}\right)^{3N/2}\frac{V^N}{\lfloor N}$

(d) $Z=\left(\frac{4\pi mU}{3h^2N}\right)^{3N/2}\frac{V^N}{\lfloor N}$

Q41. According to Heisenberg picture time evolution of any operator $A(t)$ for Hamiltonian H is given by $A(t)=\exp\left(\frac{itH}{\hbar}\right)A\exp\left(-\frac{itH}{\hbar}\right)$. If X is position operator and P is momentum operator then find the $X(t)$ for one dimensional harmonic oscillator with Hamiltonian $H=\frac{p^2}{2m}+\frac{1}{2}m\omega^2x^2$

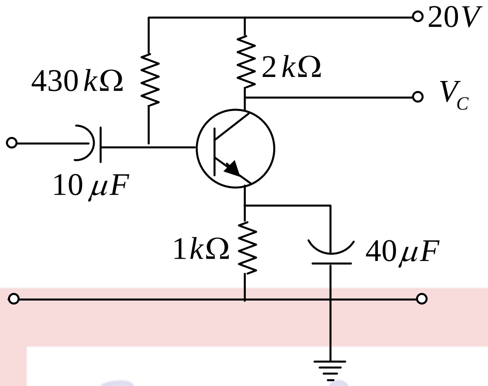
(a) $X(t)=X\cos\omega t+\frac{1}{m\omega}P\sin\omega t$

(b) $X(t)=X\sin\omega t+\frac{1}{m\omega}P\cos\omega t$

(c) $X(t)=X\cos\omega t-\frac{1}{m\omega}P\sin\omega t$

(d) $X(t)=X\sin\omega t-\frac{1}{m\omega}P\cos\omega t$

Q42. The circuit using a BJT with $\beta = 50$ and $V_{BE} = 0.7V$ is shown in the figure. The base current I_B and collector voltage V_C are respectively



(a) $43\,\mu A$ and 11.4 Volts (b) $40\,\mu A$ and 16 Volts

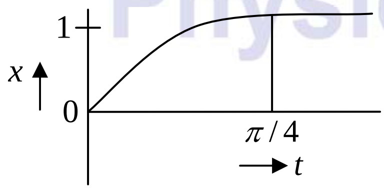
(c) $45\,\mu A$ and 11 Volts (d) $50\,\mu A$ and 10 Volts

Q43. Consider circular orbits in a central force potential $V(r) = -\frac{k}{r^n}$, where $k > 0$ and $0 < n < 2$. If the time period of a circular orbit of radius R is T_1 and that of radius $2R$ is T_2, then $\frac{T_2}{T_1}$ equals.

(a) $2^{\frac{n}{2}}$ (b) $2^{\frac{2}{3}n}$ (c) $2^{\frac{n}{2}+1}$ (d) 2^n

Q44. The solution of the differential equation $\frac{dx}{dt} = 2\sqrt{1-x^2}$, with initial condition $x = 0$ at $t = 0$ is

(a)



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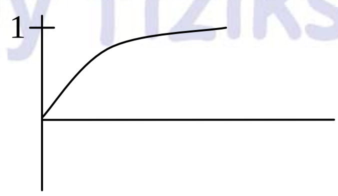

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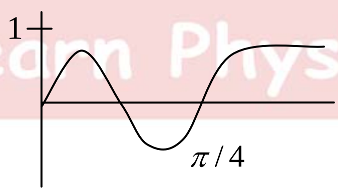

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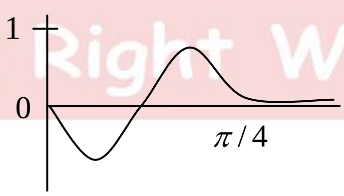


Q45. An ideal sawtooth voltage waveform of frequency $500\,Hz$ and amplitude $3V$ is generated by charging a capacitor of $2\mu F$ is every cycle. The charging requires

(a) Constant voltage source of $3V$ for $1ms$ (b) Constant voltage source of $3V$ for $2ms$

(c) Constant current source of mA for $1ms$ (d) Constant current source of $3mA$ for $2ms$

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

PART C

ANSWER ANY 20 QUESTONS

Q46. An electromagnetic wave (of wavelength λ_0 in free space) travels through an absorbing medium with dielectric permittivity ε and conductivity σ such that $\frac{\sigma}{\omega\varepsilon}=\sqrt{3}$. If the skin depth is $\frac{\lambda_0}{2\pi}$, the ratio of the amplitude of electric field E to that of the magnetic field B, in the medium is

(a) $\frac{c}{2}$ (b) $\frac{c}{3}$ (c) $\frac{c}{4}$ (d) $\frac{c}{5}$

Q47. Consider a spin $\frac{1}{2}$ particle having magnetic moment μ_0 for spin up and $-\mu_0$ for spin down with respective probabilities $\frac{2}{3}$ and $\frac{1}{3}$. If $\langle\mu\rangle$ is average value of magnetic moment and $\langle\Delta\mu\rangle$ is standard deviation for spin $\frac{1}{2}$ particle, then $\frac{\langle\Delta\mu\rangle}{\langle\mu\rangle}$ is given by

(a) $\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$ (c) $2\sqrt{2}$ (d) $\frac{1}{2\sqrt{2}}$

Q48. The Fourier series of the periodic function

$$f(x)=e^x;\quad (-\pi<x<\pi),\qquad \text{having period } 2\pi \text{ is}$$

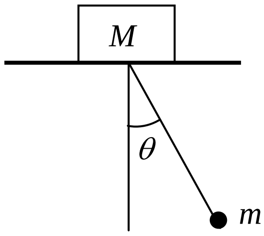
(a) $\frac{1}{\pi}\left[\frac{1}{2}-\frac{1}{1^2}(\cos x-\sin x)+\frac{1}{2^2}(\cos 2x-2\sin 2x)-+...\right]$

(b) $\frac{2}{\pi}\left[\frac{1}{2}-\frac{1}{1^2}(\cos x-\sin x)+\frac{1}{2^2}(\cos 2x-2\sin 2x)-+...\right]$

(c) $\frac{\sinh\pi}{\pi}\left[\frac{1}{2}-\frac{1}{1+1^2}(\cos x-\sin x)+\frac{1}{1+2^2}(\cos 2x-2\sin 2x)-+...\right]$

(d) $\frac{2\sinh\pi}{\pi}\left[\frac{1}{2}-\frac{1}{1+1^2}(\cos x-\sin x)+\frac{1}{1+2^2}(\cos 2x-2\sin 2x)-+...\right]$

Q49. A mass M is free to slide along a frictionless rail. A pendulum of length ℓ and mass m hangs from M. For small oscillations, the equation of motion is given by (in the equation of motion keep only linear terms in θ and $\dot{\theta}$).



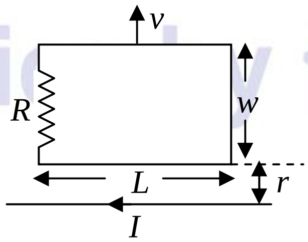
(a) $\ddot{\theta}+\left(\frac{m}{M+m}\right)\frac{g}{\ell}\theta=0$ (b) $\ddot{\theta}+\left(\frac{M}{m+M}\right)\frac{g}{\ell}\theta=0$

(c) $\ddot{\theta}+\left(\frac{M+m}{M}\right)\frac{g}{\ell}\theta=0$ (d) $\ddot{\theta}+\left(\frac{M+m}{m}\right)\frac{g}{\ell}\theta=0$

Q50. A constant perturbation H' is applied to a system for time Δt (where $H'\Delta t << \hbar$) leading to a transition from a state with energy E_i to another with energy E_f. If the time of application is halved , the probability of transition will be

(a) one fourth (b) doubled (c) quadrupled (d) halved

Q51. A rectangular loop of dimension L and width w moves with a constant velocity v away from an infinitely long straight wire carrying a current I in the plane of the loop as shown in the figure below. Let R be the resistance of the loop. What is the current in the loop at the instant the near side is at a distance r from the wire?



(a) $\frac{\mu_0 IL}{2\pi R}\frac{wv}{r[r+2w]}$ (b) $\frac{\mu_0 IL}{2\pi R}\frac{wv}{[2r+w]}$

(c) $\frac{\mu_0 IL}{2\pi R}\frac{wv}{r[r+w]}$ (d) $\frac{\mu_0 IL}{2\pi R}\frac{wv}{2r[r+w]}$

H.No. 40-D, G.F., Jia Sarai, Near IIT, Hauz Khas, New Delhi-16
Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

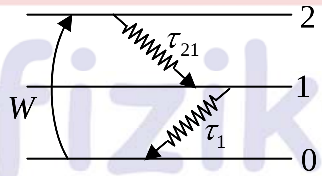
Q52. The energy vs wave vector relation near the bottom of the conduction band is

$$E = E_0 + A(Ka) + B(Ka)^2 + C(Ka)^3 + D(Ka)^4$$

where the lattice constant is $a = 3.2\,\overset{0}{\text{A}}$. The value of A, B, C and D are $2.3\times10^{-18}J, 6.4\times10^{-19}J, 5.4\times10^{-20}J$ and $8.2\times10^{-20}J$ respectively. At the bottom of the conduction band, the ratio of the effective mass of the electron to the mass of free electron is

(a) 0.1 (b) 0.01 (c) 0.05 (d) 0.08

Q53. Consider the energy level diagram shown below.



If the pump rate W is 10^{22} $atoms\text{-}cm^{-3}s^{-1}$ and the decay routes are as shown with $\tau_{21} = 9\,ns$ and $\tau_1 = 3\,ms$, the equilibrium population of state 1 is

(a) $2\times10^{12}\,cm^{-3}$ (b) $2\times10^{16}\,cm^{-3}$ (c) $2\times10^{17}\,cm^{-3}$ (d) $2\times10^{19}\,cm^{-3}$

Q54. In a thermodynamic system in equilibrium, each molecule can exist in three possible states with two of them has probabilities $1/2, 1/3$ respectively. The entropy per molecule is

(a) $k_B \ln 3$ (b) $\frac{2}{3}k_B \ln 2 + \frac{1}{2}k_B \ln 3$

(c) $\frac{1}{2}k_B \ln 2 + \frac{2}{3}k_B \ln 3$ (d) $\frac{1}{2}k_B \ln 2 + \frac{1}{6}k_B \ln 3$

Q55. Assume that a wave is travelling on a string of length 1m that is clamped at $x = 0m$ and $x = 1m$. The wave satisfies the wave equation $\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$. If $c^2 = 1, u(x,0) = kx(1-x)$ and $u_t(x,0) = 0$, then $u(x,t)$ is given by ($u_t(x,0)$ denotes the velocity of string elements at $t = 0$)

(a) $u(x,t) = \frac{8k}{\pi^3}\left(\cos\pi t \sin\pi x + \frac{1}{27}\cos 3\pi t \sin 3\pi x + \frac{1}{125}\cos 5\pi t \sin 5\pi x + \cdots\right)$

(b) $u(x,t) = \frac{8k}{\pi^3}\left(\cos\pi t \sin\pi x - \frac{1}{27}\cos 3\pi t \sin 3\pi x - \frac{1}{125}\cos 5\pi t \sin 5\pi x - \cdots\right)$

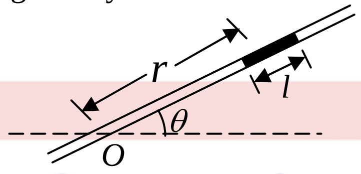
(c) $u(x,t) = \frac{4k}{\pi^3}\left(\cos\pi t \sin\pi x + \frac{1}{27}\cos 3\pi t \sin 3\pi x + \frac{1}{125}\cos 5\pi t \sin 5\pi x + \cdots\right)$

(d) $u(x,t) = \frac{4k}{\pi^3}\left(\cos\pi t \sin\pi x - \frac{1}{27}\cos 3\pi t \sin 3\pi x - \frac{1}{125}\cos 5\pi t \sin 5\pi x - \cdots\right)$

Q56. Consider a $150\,m$ long air-filled hollow rectangular waveguide with cutoff frequency $6.5\,GHz$. If a short pulse of 7.2 GHz is introduced into the input end of the guide, the time taken by the pulse to return the input end is:

(a) 920 ns (b) 460 ns (c) 230 ns (d) 430 ns

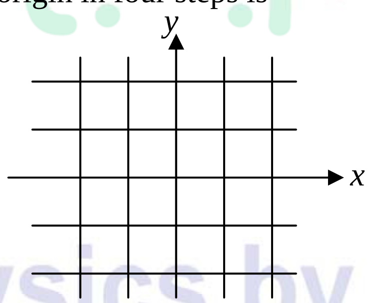
Q57. A long thin tube of negligible mass is pivoted so that it may rotate without friction in a horizontal plane as shown in figure. A thin rod uniform of mass M and length I slides without friction in the tube. If ω is angular velocity then angular momentum of system with respect to origin O is given by



(a) $Mr^2\omega$ (b) $\frac{MI^2\omega}{12}$

(c) $Mr^2\omega+\frac{MI^2\omega}{12}$ (d) $Mr^2\omega+\frac{MI^2\omega}{3}$

Q58. In a square lattice as shown in the figure, a particle starts from origin. If the particle can move only in x or y direction and the probability of each direction is $\frac{1}{4}$, the probability that particle will return to origin in four steps is



(a) $\frac{1}{4}$ (b) $\frac{1}{8}$ (c) $\frac{1}{16}$ (d) $\frac{3}{16}$

Q59. Using trial wave function $\psi = e^{-\alpha r^2}$, the ground state energy of potential $V(r)=kr$ is $\alpha\left(\frac{9k^4\hbar^4}{16\pi^2m^2}\right)^{1/6}$ then value of α is

(a) 1 (b) 2 (c) 3 (d) 4

Q60. The Fermi energies of two metals x and y are $4eV$ and $6eV$ and their Debye temperatures are $180\,K$ and $320\,K$, respectively. The molar specific heats of these metals at constant volume at low temperature can be written as

(a) $\frac{A_x}{A_y}=\frac{3}{2}, \frac{B_x}{B_y}=3$ (b) $\frac{A_x}{A_y}=\frac{2}{3}, \frac{B_x}{B_y}=3.5$

(c) $\frac{A_x}{A_y}=\frac{3}{2}, \frac{B_x}{B_y}=4.8$ (d) $\frac{A_x}{A_y}=\frac{3}{2}, \frac{B_x}{B_y}=8.6$

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Phone: 011-26865455/+91-9871145498, Website: www.physicsbyfiziks.com, Email: fiziks.physics@gmail.com

Q61. In an infinite straight wire constant current I_0 is turned on abruptly at $t=0$. The corresponding retarded potentials are given by

$$V(\vec{r},t)=0, \qquad \vec{A}(\vec{r},t)=\frac{\mu_0 I_0}{2\pi}\ln\left(\frac{ct+\sqrt{(ct)^2-r^2}}{r}\right)\hat{z}$$

Then the electric field corresponding to these potentials is:

(a) $\frac{\mu_0 I_0}{2\pi r}\frac{ct}{\sqrt{(ct)^2-r^2}}\hat{\phi}$ (b) $-\frac{\mu_0 I_0}{2\pi r}\frac{ct}{\sqrt{(ct)^2-r^2}}\hat{\phi}$

(c) $\frac{\mu_0 I_0 c}{2\pi\sqrt{(ct)^2-r^2}}\hat{z}$ (d) $-\frac{\mu_0 I_0 c}{2\pi\sqrt{(ct)^2-r^2}}\hat{z}$

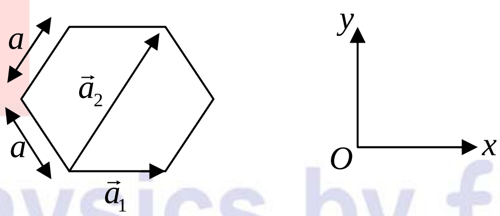
Q62. Match the reaction on the left with the associated reaction on the right

1 $\Delta^{++}\rightarrow p+\pi^{+}$	(i) $us\rightarrow dd+\bar{d}$
2. $\Sigma^{+}\rightarrow n+\pi^{+}$	(ii) $dd\rightarrow ud+\bar{u}$
3. $\Sigma^{-}\rightarrow n+\pi^{-}$	(iii) $uu\rightarrow ud+\bar{d}$
4. $\Delta^{-}\rightarrow n+\pi^{-}$	(iv) $ds\rightarrow ud+\bar{u}$

(a) (1-i), (2-ii), (3-iii), (4-iv) (b) (1-ii), (2-iii), (3-iv), (4-i)

(c) (1-iii), (2-i), (3-iv), (4-ii) (d) (1-iv), (2-iii), (3-ii), (4-i)

Q63. The real space primitive lattice vectors $\vec{a}_1$ and $\vec{a}_2$ of Graphene lattice are shown in the figure below



The area of the first Brillouin zone is

(a) $\frac{\pi^2}{\sqrt{3}a^2}$ (b) $\frac{2\pi^2}{\sqrt{3}a^2}$ (c) $\frac{4\pi^2}{\sqrt{3}a^2}$ (d) $\frac{8\pi^2}{\sqrt{3}a^2}$

Q64. Consider the following set of points $(-2,-1),(1,1),(3,2)$. Which of the following correctly represent the least square regression line for the given data points

(a) $y=0.26x+0.82$ (b) $y=0.827+0.26$

(c) $y=0.35x+0.92$ (d) $y=0.92x+0.35$

Q65. An amplifier using an op-amp with a slew-rate $SR=1V/\mu\sec$ has a gain of $40dB$. If this amplifier has to faithfully amplify sinusoidal signals from dc to $20kHz$ without introducing any slew-rate induced distortion, then the input signal level must not exceed.

(a) $795mV$ (b) $395mV$ (c) $79.5mV$ (d) $39.5mV$

Q66. The first three energy levels of ${}^{235}U_{92}$ are shown below

4^{+} ———— $148\,keV$

2^{+} ———— $45\,keV$

0^{+} ———— $0\,keV$

The expected spin parity and energy of the next level is given by

(a) $\left(6^{+}, 307\,keV\right)$ (b) $\left(6^{+}, 400\,keV\right)$ (c) $\left(8^{+}, 420\,keV\right)$ (d) $\left(8^{+}, 460\,keV\right)$

Q67. In the phase transition from liquid state to vapour state the heat of vaporization is $L = a - bT$ (a and $b > 0$). Assume that the gas behave nearly Ideal. If the critical pressure at critical temperature T_c is P_c then pressure of liquid when temperature is $\frac{T_C}{2}$ is given by

(a) $P = P_c \exp\left[\frac{1}{R}\left(b\frac{3T_c^2}{8} - a\frac{T_c}{2}\right)\right]$ (b) $P = P_c \exp\left[-\frac{1}{R}\left(b\frac{3T_c^2}{8} - a\frac{T_c}{2}\right)\right]$

(c) $P = P_c \exp\left[\frac{1}{R}\left(b\frac{T_c^2}{8} - a\frac{T_c}{2}\right)\right]$ (d) $P = P_c \exp\left[-\frac{1}{R}\left(b\frac{T_c^2}{8} - a\frac{T_c}{2}\right)\right]$

Q68. A radioactive element A has a half-life of 100 hours. It decays via alpha, beta and gamma emission with branching ratio for beta decay being 0.70. The partial half-life for beta decay in units of hours is

(a) 108 (b) 124 (c) 143 (d) 152

Q69. The volume of an optical cavity is $2\,cm^3$. The number of modes it can support within a bandwidth of $0.5\,nm$, centered at $6893\,\overset{0}{\mathrm{A}}$, is of the order of

(a) 10^{9} (b) 10^{10} (c) 10^{11} (d) 10^{12}

Q70. The resolution of a $4-$bit counting ADC 0.5 volts. For an analog input of 6.6 volts, the digital output of the ADC will be

(a) 1011 (b) 1101 (c) 1100 (d) 1110

Q71. Compute the value of $\frac{2}{\sqrt{\pi}}\int_0^x e^{-x^2}dx$ when $x = 0\cdot 6538$ using Gauss's forward formula also taking origin at $0\cdot 65, h = 0\cdot 01$ and $x = 0\cdot 6538$, Use the given table

x	y
0.62	0.6194114
0.63	0.6270463
0.64	0.6345857

0.65	0.6420292
0.66	0.6493765
0.67	0.6566275
0.68	0.6637820

(a) 0.6448325 (b) 0.7448325 (c) 0.8448325 (d) 0.5448325

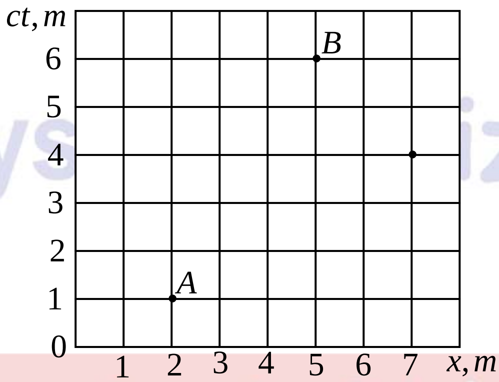
Q72. The diatomic molecule $^{1}HCl^{35}$ has an absorption line in the rotational band at $83.03\,cm^{-1}$ for $J = 3 \rightarrow 4$. The corresponding line for the isotope $^{1}HCl^{37}$ will be shifted by approximately

(a) $0.16\,cm^{-1}$ (b) $0.59\,cm^{-1}$ (c) $0.98\,cm^{-1}$ (d) $1.1\,cm^{-1}$

Q73. A particle of mass m is contained in a one-dimensional infinite well extending from $x = -\frac{L}{2}$ to $x = \frac{L}{2}$. The particle is in its ground state given by $\varphi_0(x) = \sqrt{2/L}\cos(\pi x/L)$. The walls of the box are moved suddenly to form a box extending from $x = -L$ to $x = L$. What is the probability that the particle will be in the ground state after this sudden expansion?

(a) $\frac{16}{9\pi^2}$ (b) $\frac{64}{9\pi^2}$ (c) $\frac{128}{81\pi^2}$ (d) $\frac{256}{81\pi^2}$

Q74. The space-time diagram of figure shows three events A, B, which occurred on the x-axis of some inertial reference frame.



the time interval between the events A and B in the reference frame where the two events occurred at the same point.

(a) 0 (b) $1.3\times10^{-8}\,s$ (c) $13\times10^{-8}\,s$ (d) $25\times10^{-8}\,s$

Q75. The free energy F of a system depends on a magnetization variable $M(T)$ as

$$F = -aM^2 + bM^6$$

with $a, b > 0$. The value of M, when the system is in thermodynamic equilibrium, is

(a) zero (b) $\pm(a/6b)^{1/4}$ (c) $\pm(a/3b)^{1/4}$ (d) $\pm(a/b)^{1/4}$
