An Institute of NET-JRF, IIT-JAM, GATE, JEST, TIFR & M.Sc Entrance in Physics & Physical Sciences

NET- Joint CSIR UGC Examination June-2021
Physics

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NET- Joint CSIR UGC Examination June-2021

Examination Date 15-02-2022

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

Instructions

This Test Paper contains seventy-five (20 Part 'A' + 25 Part 'B' + 30 Part 'C') Multiple Choice Questions (MCQs). You are required to answer a maximum of 15 in part 'A', 20 in Part 'B', and 20 in Part 'C'. If more than the required number of questions are answered then only the first 15, 20, 20 questions in Parts 'A', 'B', and 'C' respectively, will be taken up for evaluation. Each question in Part 'A' carries two marks, Part 'B' 3.5 marks and Part 'C' 5 marks respectively. The total marks allocated 30, 70, and 100 for Parts 'A', 'B' and 'C' respectively. There will be a negative marking @25% for each wrong answer. Below each question in Parts 'A', 'B' and 'C' four alternatives or responses are given. Only one of these alternatives is the "CORRECT" option to the question. You have to find, for each question, the correct or best answer.

Part A

ANSWER ANY 15 QUESTIONS

Q1. The arithmetic and geometric means of two numbers are 65 and 25, respectively. What are these two numbers?

(a) $110, 20$ (b) $115, 15$ (c) $120, 10$ (d) $125, 5$

Ans. 1: (d)

Q2. An intravenous fluid is given to a child of $7.5\,kg$, at the rate of 20 drop/minute. The prescribed dose of the fluid is 40 ml per kg of body weight. If the volume of a drop is 0.05 ml, how many hours are needed to complete the dose?

(a) 2 (b) 3 (c) 4 (d) 5

Ans. 2: (d)

Q3. Shyam spent half of his money and was left with as many as he had rupees before, but with half as many rupees as he had paise before. Which of the following is a possible amount of money he is left with?

(a) 49 rupees and 98 paise (b) 49 rupees and 99 paise

(c) 99 rupees and 99 paise (d) 99 rupees and 98 paise

Ans. 3: (b)

Q4. How many integers in the set $\{1, 2, 3, ..., 100\}$ have exactly 3 divisors?

(a) 4 (b) 12 (c) 5 (d) 9

Ans. 4: (a)

Q5. A spacecraft flies at a constant height R above a planet of radius R. At the instant the spacecraft is over the north-pole, the lowest latitude visible from the spacecraft is:

(a) 0° (Equator) (b) $30^\circ N$ (c) $45^\circ N$ (d) $60^\circ N$

Ans. 5: (b)

Q6. Identical balls are tightly arranged in the shape of an equilateral triangle with each side containing n balls. How many balls are there in the arrangement?

(a) $n^2/2$ (b) $n(n+1)/2$ (c) $n(n-1)/2$ (d) $(n+1)^2/2$

Ans. 6: (b)

Q7. A and B start from the same point in opposite directions along a circular track simultaneously. Speed of B is $2/3^{rd}$ that of A. How many times will A and B cross each other before meeting at the starting point?

(a) 2 (b) 3 (c) 5 (d) 4

Ans. 7: (d)

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Q8. An experiment consists of tossing a coin 20 times. Such an experiment is performed 50 times. The number of heads and the number of tails in each experiment are noted. What is the correlation coefficient between the two?

(a) -1 (b) $-20/50$ (c) $20/50$ (d) 1

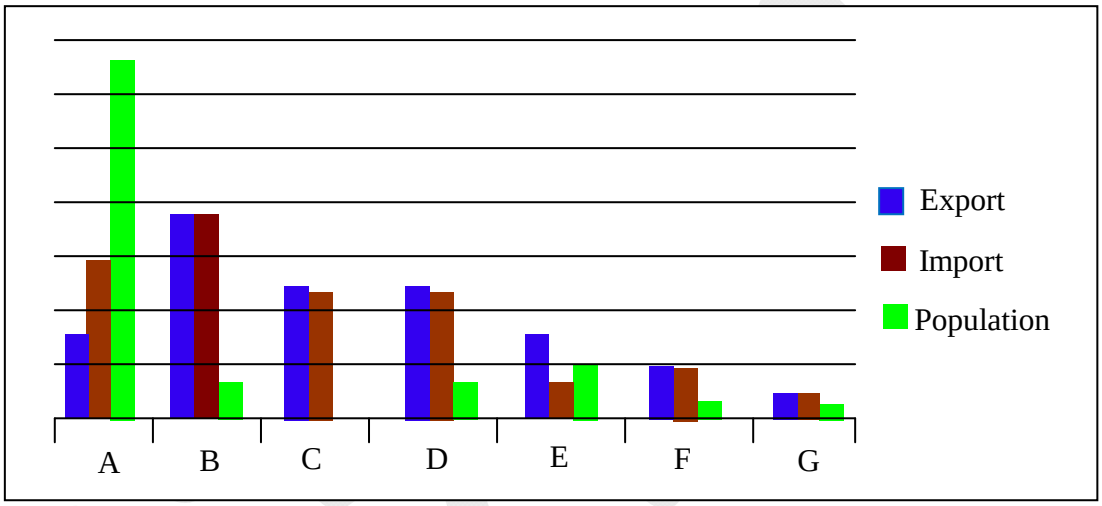
Ans. 8: (a)

Q9. The maximum area of a right-angled triangle inscribed in a circle of radius r is

(a) $2r^2$ (b) $r^2/2$ (c) $\sqrt{2}r^2$ (d) r^2

Ans. 9: (d)

Q10. Trade figures populations in appropriate units in a certain year are given for 7 countries.



If countries are ranked according to the difference in their per capita exports over import, the best and worst ranking countries are respectively.

(a) C and A (b) A and E (c) C and B (d) A and F

Ans. 10: (a)

Q11. A cylindrical road roller having a diameter of $1.5m$ moves at a speed of $3km/h$ while levelling a road. How much length of the road will be leveled in 45 minutes?

(a) $2.25\,km$ (b) $0.375\pi km$ (c) $0.75\pi km$ (d) $1.5\,kn$

Ans. 11: (a)

Q12. Which of these groups of numbers has the smallest mean?

Group A: $1,2,3,4,5,6,7,8,9$

Group B: $1,2,3,4,6,6,7,8,9$

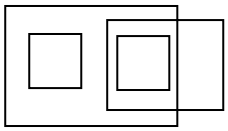
Group C: $1,2,2,4,5,6,7,8,9$

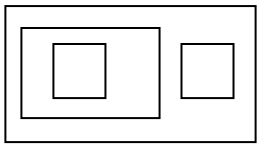
Group D: $1,3,3,4,5,6,7,9,9$

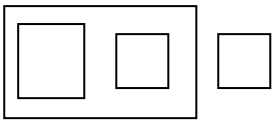
(a) A (b) B (c) C (d) D

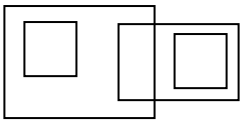
Ans. 12: (c)

Q13. An appropriate diagram to represent the relations between the categories KEYBOARD, HARDWARE, OPERATING SYSTEM and *CPU* is

(a) 

(b) 

(c) 

(d) 

Ans. 13: (c)

Q14. If we replace the mathematical operations in the expression $(11+4-2)\div 24\times 6$ as given in the table:

Operation	+	−	×	÷
Replaced by	−	×	÷	+

Then is new value is

(a) $23/6$ (b) 1 (c) 18 (d) 7

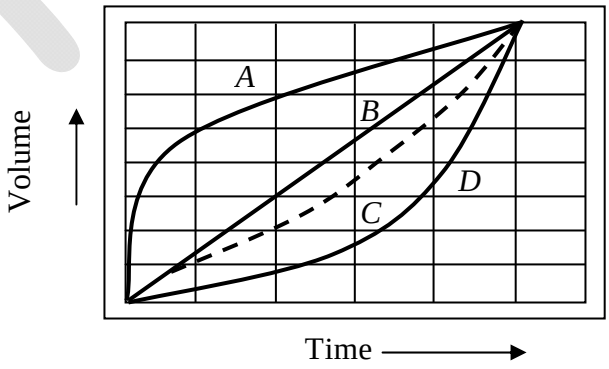
Ans. 14: (d)

Q15. In a tournament with 8 teams, a win fetches 3 points and a draw, 1. After all teams have played three matches each, total number of points earned by all teams put together must lie between

(a) 24 and 36 (b) 24 and 32 (c) 12 and 24 (d) 32 and 48

Ans. 15: (a)

Q16. An inverted cone is filled with water at a constant rate. The volume of water inside the cone as a function of times is represented the curve



(a) *A* (b) *B* (c) *C* (d) *D*

Ans. 16: (b)

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Q17. At least two among three persons A, B and C are truthful. If A calls B a liar and if B calls C a liar, then which of the following is FALSE?

(a) A is truthful (b) B is truthful

(c) C is truthful (d) At least one is a liar

Ans. 17: (b)

Q18. A shopkeeper has a faulty pan balance with a zero offset. When an object is placed in the left plan it is balanced by a standard $100g$ weight. When it is placed in the right pan it is balanced by a standard $80g$ weight. What is the actual weight of the object?

(a) $90g$ (b) $88.88g$ (c) $95\,g$ (d) $85\,g$

Ans. 18: (a)

Q19. A cousin is a non-sibling with a common ancestor. If there is exactly one pair of siblings in a group of 5 persons then the maximum possible number of pairs of cousins in the group is

(a) 3 (b) 6 (c) 9 (d) 10

Ans. 19: (c)

Q20. Consider a solid cube of side 5 units. After painting, it is cut into cubes of 1 unit. Find the probability that a randomly chosen unit cube has only one side painted.

(a) $56/125$ (b) $36/125$ (c) $44/125$ (d) $54/125$

Ans. 20: (d)

Part B

ANSWER ANY 20 QUESTIONS

Q21. Which of the following two physical quantities cannot be measured simultaneously with arbitrary accuracy for the motion of a quantum particle in three dimensions?

(a) square of the radial position and z-component of angular momentum (r^2 and L_z)

(b) x- components of linear and angular momenta (p_x and L_x)

(c) y-component of position and z-component of angular momentum (y and L_x)

(d) squares of the magnitudes of the linear and angular momenta (p^2 and L^2)

Ans. 21: (c)

Q22. A particle in one dimension executes oscillatory motion in a potential $V(x) = A|x|$, where $A > 0$ is a constant of appropriate dimension. If the time period T of its oscillation depends on the total energy E as E^a, then the value of a is

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

Ans. 22: (b)

Q23. The components of the electric field, in a region of space devoid of any change or current sources, are given to be $E_i = a_i + \sum_{j=1,2,3} b_{ij} x_j$, where a_i and b_{ij} are constants independent of the coordinates. The number of independent components of the matrix b_{ij} is

(a) 5 (b) 6 (c) 3 (d) 4

Ans. 23: (a)

Q24. A particle of mass $1 GeV/c^2$ and its antiparticle, both moving with the same speed v, produce new particle x of mass $10 GeV/c^2$ in a head on collision. The minimum value of v required for this process is closest to

(a) $0.83c$ (b) $0.93c$ (c) $0.98c$ (d) $0.88c$

Ans. 24: (c)

Q25. The position of a particle in one dimension changes in discrete steps. With each step it moves to the right, however, the length of the step is drawn from a uniform distribution from the interval $\left[\lambda - \frac{1}{2}w, \lambda + \frac{1}{2}w\right]$, where λ and w are positive constants. If X denotes the distance from the starting point after N steps, the standard deviation $\sqrt{\langle X^2 \rangle - \langle X \rangle^2}$ for large values of N is

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(a) $\frac{\lambda}{2}\times\sqrt{N}$ (b) $\frac{\lambda}{2}\times\sqrt{\frac{N}{3}}$ (c) $\frac{w}{2}\times\sqrt{N}$ (d) $\frac{w}{2}\times\sqrt{\frac{N}{3}}$

Ans. 25: (d)

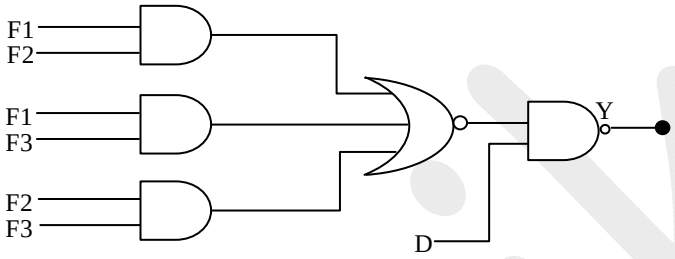
Q26. The volume of the region common to the interiors of two infinitely long cylinders defined by $x^2+y^2=25$ and $x^2+4z^2=25$ is best approximated by

(a) 225 (b) 333 (c) 423 (d) 625

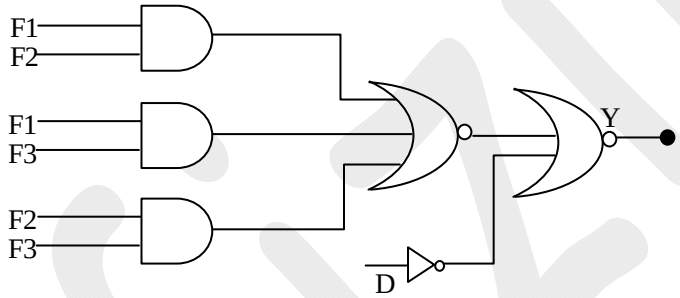
Ans. 26: (b)

Q27. The door of an X -ray machine room is fitted with a sensor D (0 is open and 1 is closed). It is also equipped with three fire sensors F_1, F_2 and F_3 (each is 0 when disabled and 1 when enabled). The X -ray machine can operate only if the door is closed and at least 2 fire sensors are enabled. The logic circuit to ensure that the machine can be operated is

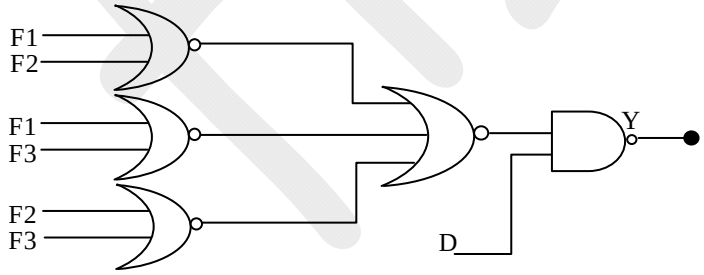
(a)



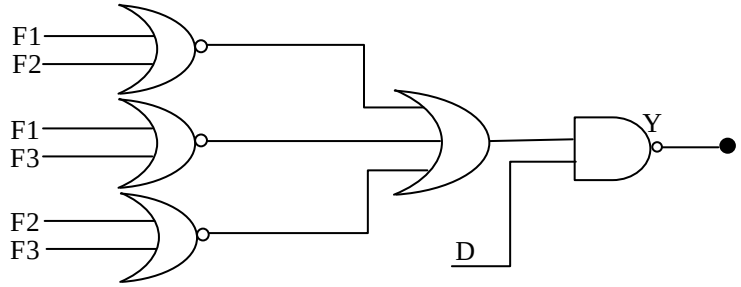
(b)



(c)

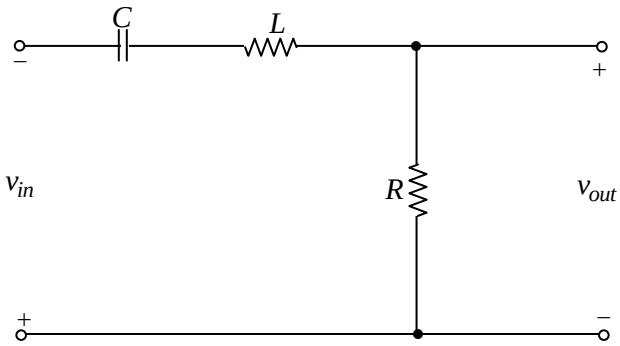


(d)



Ans. 27: (b)

Q28. In the LCR circuit shown below, the resistance $R = 0.05\Omega$, the inductance $L = 1H$ and the capacitance $C = 0.04F$.



If the input v_{in} is a square wave of angular frequency $1 rad/s$, the output v_{out} is best approximated by a

(a) Square wave of angular frequency $1 rad/s$

(b) Sine wave of angular frequency $1 rad/s$

(c) Square wave of angular frequency $5 rad/s$

(d) Sine wave of angular frequency $5 rad/s$

Ans. 28: (d)

Q29. A monochromatic source emitting radiation with a certain frequency moves with a velocity v away from a stationary observer A. It is moving towards another observer B (also at rest) along a line joining the two. The frequencies of the radiation recorded by A and B are V_A and V_B, respectively. If the ratio $\frac{V_B}{V_A} = 7$, then the value of v/c is

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

Ans. 29: (c)

Q30. A particle, thrown with a speed v from the earth's surface, attains a maximum height h (measured from the surface of the earth). If v is half the escape velocity and R denotes the radius of earth, then h/R is

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

Ans. 30: (b)

Q31. A particle of mass m is in a one dimensional infinite potential well of length L, extending from $x = 0$ to $x = L$. When it is in the energy Eigen-state labelled by $n, (n = 1, 2, 3, ..)$ the probability of finding in the interval $0 \le x \le L/8$ is 1/8. The minimum value of n for which this is possible is

(a) 4 (b) 2 (c) 6 (d) 8

Ans. 31: (a)

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Q32. In an experiment, the velocity of a non-relativistic neutron is determined by measuring the time $(\sim 50\,ns)$ it takes to travel from the source to the detector kept at a distance L. Assume that the error in the measurement of L is negligibly small. If we want to estimate the kinetic energy T of the neutron to within 5% accuracy, i.e., $|\delta T/T| \le 0.05$, the maximum permissible error $|\delta T|$ in measuring the time of flight is nearest to

(a) $1.75\,ns$ (b) $0.75\,ns$ (c) $2.25\,ns$ (d) $1.25\,ns$

Ans. 32: (d)

Q33. The volume and temperature of a spherical cavity filled with black body radiation are V and $300K$, respectively. If it expands adiabatically to a volume $2V$, its temperature will be closest to

(a) $150\,K$ (b) $300\,K$ (c) $250\,K$ (d) $240\,K$

Ans. 33: (d)

Q34. The ratio c_p/c_v of the specific heats at constant pressure and volume of a monatomic ideal gas in two dimensions is

(a) $3/2$ (b) 2 (c) $5/3$ (d) $5/2$

Ans. 34: (2)

Q35. The total number of phonon modes in a solid of volume V is $\int_0^{\omega_D} g(\omega)\,d\omega = 3N$, is the number of primitive cells, ω_D is the Debye frequency and density of photon modes is $g(\omega) = AV\omega^2$ (with $A > 0$ a constant). If the density of the solid doubles in a phase transition, the Debye temperature θ_D will

(a) increase by a factor of $2^{2/3}$ (b) increase by a factor of $2^{1/3}$

(c) decrease by a factor of $2^{2/3}$ (d) decrease by a factor of $2^{1/3}$

Ans. 35: (b)

Q36. A discrete random variable X takes a value from the set $\{-1,0,1,2\}$ with the corresponding probabilities $p(X) = 3/10, 2/10, 2/10$ and $3/10$, respectively. The probability distribution $q(Y) = (q(0), q(1), q(4))$ of the random variable $Y = X^2$ is

(a) $\left(\frac{1}{5},\frac{3}{5},\frac{1}{5}\right)$ (b) $\left(\frac{1}{5},\frac{1}{2},\frac{3}{10}\right)$ (c) $\left(\frac{2}{5},\frac{2}{5},\frac{1}{5}\right)$ (d) $\left(\frac{3}{10},\frac{3}{10},\frac{2}{5}\right)$

Ans. 36: (b)

Q37. In an experiment to measure the charge to mass ratio e/m of the electron by Thomson's method, the values of the deflecting electric field and the accelerating potential are $6\times10^6\,N/C$ (newton per coulomb) and $150V$, respectively. The magnitude of the magnetic field that leads to zero deflection of the electron beam is closest to

(a) $0.6T$ (b) $1.2T$ (c) $0.4T$ (d) $0.8T$

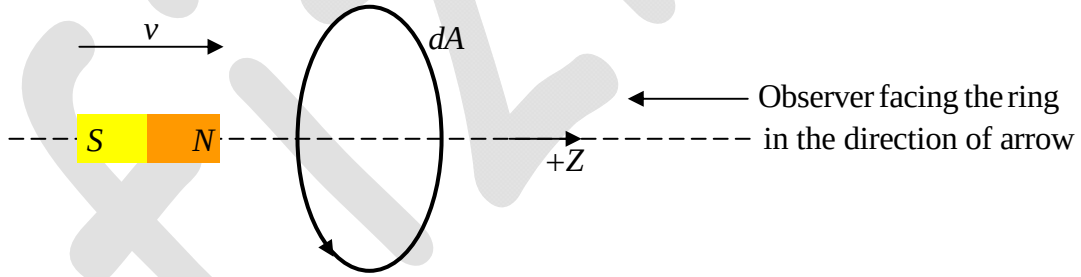
Ans. 37: (d)

Q38. A two-state system evolves under the action of the Hamiltonian $H = E_0|A\rangle\langle A| + (E_0+\Delta)|B\rangle\langle B|$, where $|A\rangle$ and $|B\rangle$ are its two orthonormal states. These states transform to one another under parity, i.e. $P|A\rangle = |B\rangle$ and $P|B\rangle = |A\rangle$. If at time $t=0$ the system is in a state of definite parity $P=1$, the earliest time t at which the probability of finding the system in a state of parity $P=-1$ is one is

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

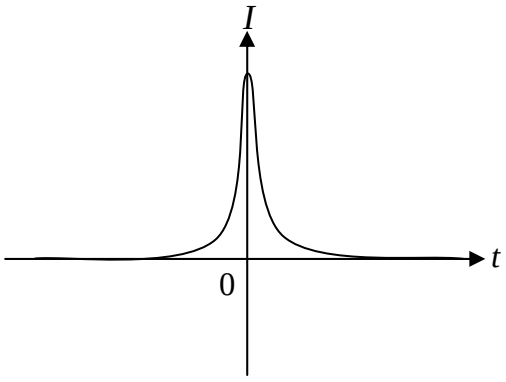
Ans. 38: (b)

Q39. A conducting wire in the shape of a circle lies on the (x,y)-plane with its centre at the origin. A bar magnet moves with a constant velocity towards the wire along the z-axis (as shown in the figure below).



We take $t=0$ to be the instant at which the midpoint of the magnet is at the centre of the wire loop and the induced current to be positive when it is counter-clockwise as viewed by the observer facing the loop and the incoming magnet. In these conventions, the best schematic representation of the induced current $I(t)$ as a function of t, is

(a)



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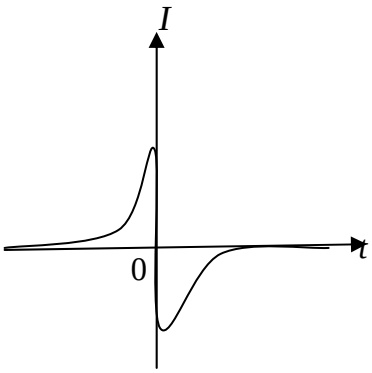

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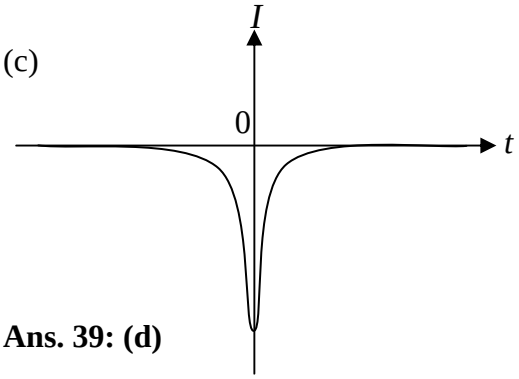
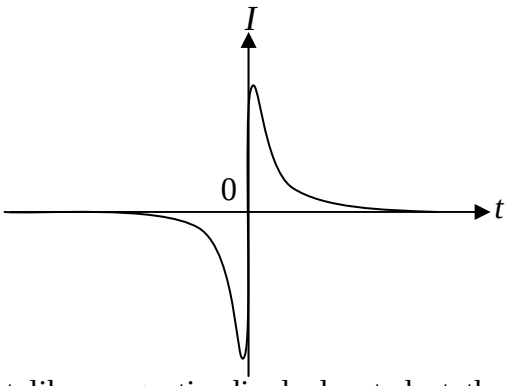
(c)



(d)



Ans. 39: (d)

Q40. The vector potential for an almost point like magnetic dipole located at the origin is $\vec{A}=\frac{\mu \sin\theta}{4\pi r^2}\hat{\phi}$ where (r,θ,ϕ) denote the spherical polar coordinates and $\hat{\phi}$ is the unit vector along $\hat{\phi}$. A particle of mass m and charge q, moving in the equatorial plane of the dipole, starts at time $=t=0$ with an initial speed v_0 and an impact parameter b. Its instantaneous speed at the point of closest approach is

(a) v_0 (b) $0/0$ (c) $v_0+\frac{\mu q}{4\pi m b^2}$ (d) $\sqrt{v_0^2+\left(\frac{\mu q}{4\pi m b^2}\right)^2}$

Ans. 40: (a)

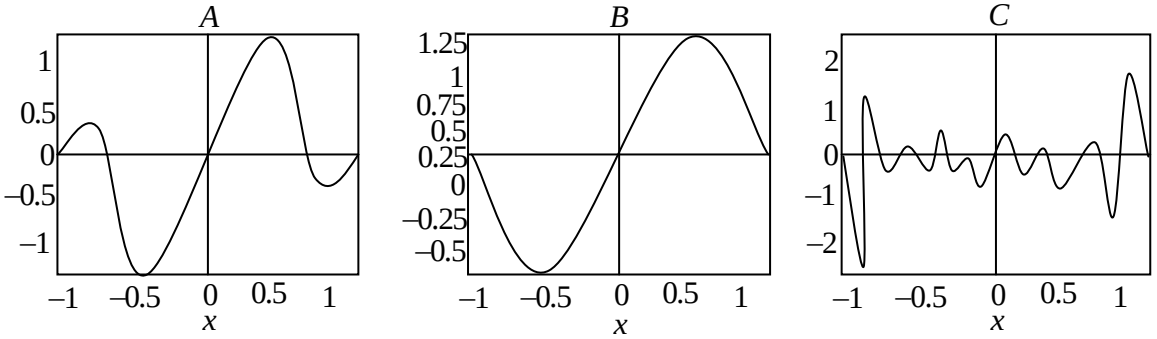
Q41. The equation of motion of a one-dimensional forced harmonic oscillator in the presence of a dissipative force is described by $\frac{d^2x}{dt^2}+10\frac{dx}{dt}+16x=6te^{-8t}+4t^2e^{-2t}$. The general form of the particular solution, in terms of constants A, B etc ., is

(a) $t\left(At^2+Bt+C\right)e^{-2t}+\left(Dt+E\right)e^{-8t}$ (b) $\left(At^2+Bt+C\right)e^{-2t}+\left(Dt+E\right)e^{-8t}$

(c) $t\left(At^2+Bt+C\right)e^{-2t}+t\left(Dt+E\right)e^{-8t}$ (d) $\left(At^2+Bt+C\right)e^{-2t}+t\left(Dt+E\right)e^{-8t}$

Ans. 41: (c)

Q42. The figures below depict three different wave functions of a particle confined to a one dimensional box $-1\le x\le 1$



The wave functions that correspond to the maximum expectation values $\left|\langle x\rangle\right|$ (absolute value of the mean position) and $\langle x^2\rangle$, respectively, are

(a) B and C (b) B and A (c) C and B (d) A and B

Ans. 42: (a)

Q43. The Hamiltonian of a particle of mass m in one-dimension is $H=\frac{1}{2m}p^2+\lambda|x|^3$, where $\lambda>0$ is a constant. If E_1 and E_2 respectively, denote the ground state energies of the particle for $\lambda=1$ and $\lambda=2$ (in appropriate units) the ratio E_2/E_1 is best approximated by

(a) 1.260 (b) 1.414 (c) 1.516 (d) 1.320

Ans. 43: (d)

Q44. A generic 3×3 real matrix A has eigenvalues 0,1 and 6, and I is the 3×3 identity matrix. The quantity/quantities that cannot be determined from this information is/are the

(a) eigenvalue of $(I+A)^{-1}$ (b) eigenvalue of $(I+A^TA)$

(c) determinant of A^TA (d) rank of A

Ans. 44: (b)

Q45. The volume integral $I=\iiint_V \vec{A}\cdot(\vec{\nabla}\times\vec{A})d^3x$, is over a region V bounded by a surface $\sum$ (an infinitesimal area element being $\hat{n}ds$, where $\hat{n}$ is the outward unit normal). If it changes to $I+\Delta I$ when the vector $\vec{A}$ is changed to $\vec{A}+\vec{\nabla}\Lambda$, then ΔI can be expressed as

(a) $\iiint_V \vec{\nabla}\cdot(\vec{\nabla}\Lambda\times\vec{A})d^3x$ (b) $-\iiint_V \nabla^2\Lambda\, d^3x$

(c) $-\oiint_\Sigma(\vec{\nabla}\Lambda\times\vec{A}).\hat{n}ds$ (d) $\oiint_\Sigma \vec{\nabla}\Lambda.\hat{n}ds$

Ans. 45: (c)

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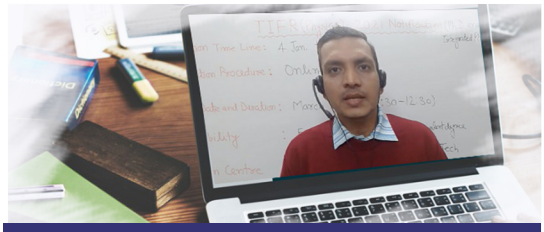

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Part C

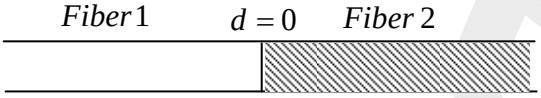
ANSWER ANY 20 QUESTIONS

Q46. The Newton-Raphson method is to be used to determine the reciprocal of the number $x = 4$. If we start with the initial guess 0.20 then after the first iteration the reciprocal is

(a) 0.23 (b) 0.24 (c) 0.25 (d) 0.26

Ans. 46: (b)

Q47. A laser beam propagates from fiber 1 to fiber 2 in a cavity made up of two optical fibers (as shown in the figure). The loss factor of fiber 2 is $10\,dB/km$.

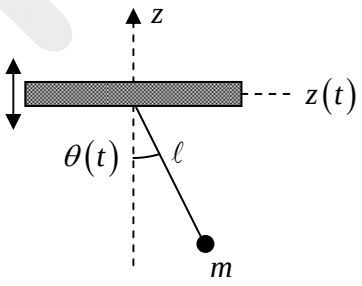


If $E_2(d)$ denotes the magnitude of the electric field in fiber 2 at a distance d from the interface, the ratio $E_2(0)/E_2(d)$ for $d = 10\,km$, is

(a) 10^2 (b) 10^3 (c) 10^5 (d) 10^7

Ans. 47: (c)

Q48. The fulcrum of a simple pendulum (consisting of a particle of mass m attached to the support by a massless string of length ℓ) oscillates vertically as $\sin z(t) = a\sin\omega t$, where ω is a constant. The pendulum moves in a vertical plane and $\theta(t)$ denotes its angular position with respect to the z-axis



If $\ell\dfrac{d^2\theta}{dt^2} + \sin\theta\left(g - f(t)\right) = 0$ (where g is the acceleration due to gravity) describes the equation of motion of the mass, then $f(t)$ is

(a) $a\omega^2\cos\omega t$ (b) $a\omega^2\sin\omega t$ (c) $-a\omega^2\cos\omega t$ (d) $-a\omega^2\sin\omega t$

Ans. 48: NOT Given

Q49. The energies of a two-state quantum system are E_0 and $E_0+\alpha\hbar$, (where $\alpha>0$ is a constant) and the corresponding normalized state vectors are $|0\rangle$ and $|1\rangle$, respectively. At time $t=0$, when the system is in the state $|0\rangle$, the potential is altered by a time independent term V such that $\langle 1|V|0\rangle=\hbar\alpha/10$. The transition probability to the state $|1\rangle$ at times $t\ll 1/\alpha$, is

(a) $\alpha^2t^2/25$ (b) $\alpha^2t^2/50$ (c) $\alpha^2t^2/100$ (d) $\alpha^2t^2/200$

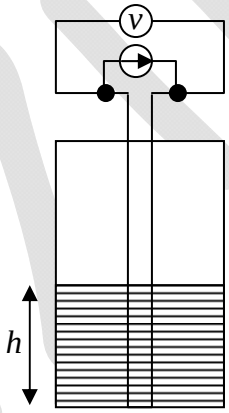
Ans. 49: (c)

Q50. The nuclei of ^{137}Cs decay by the emission of β -particles with a half-life of 30.08 years. The activity (in units of disintegrations per second or Bq) of a $1mg$ source of ^{137}Cs, prepared on January 1, 1980, as measured on January 1, 2021 is closest to

(a) 1.79×10^{16} (b) 1.79×10^{9} (c) 1.24×10^{16} (d) 1.24×10^{9}

Ans. 50: (d)

Q51. To measure the height h of a column of liquid helium in a container, a constant current I is sent through an $NbTi$ wire of length l, as shown in the figure. The normal state resistance of the $NbTi$ wire is R.



If the superconducting transition temperature of $NbTi$ is $\approx 10\,K$, then the measured voltage $V(h)$ is best described by the expression

(a) $IR\left(\frac{1}{2}-\frac{2h}{l}\right)$ (b) $IR\left(1-\frac{h}{l}\right)$ (c) $IR\left(\frac{1}{2}-\frac{h}{l}\right)$ (d) $IR\left(1-\frac{2h}{l}\right)$

Ans. 51: (d)

Q52. Diffuse hydrogen gas within a galaxy may be assumed to follow a Maxwell distribution at temperature $10^6\,K$, while the temperature appropriate for the H gas in the inter-galactic space, following the same distribution, may be taken to be $10^4\,K$. The ratio of thermal broadening $\Delta\nu_G/\Delta\nu_{IG}$ of the Lyman-α line from the H-atoms within the galaxy to that from the inter-galactic space is closest to

(a) 100 (b) 1/100 (c) 10 (d) 1/10

Ans. 52: (c)

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Q53. The dispersion relation of a gas of non-interacting bosons in d dimensions $E(k) = ak^s$ where a and s are positive constants, Bose-Einstein condensation will occur for all values of

(a) $d > s$ (b) $d + 2 > s > d - 2$

(c) $s > 2$ independent of d (d) $d > 2$ independent of s

Ans. 53: (a)

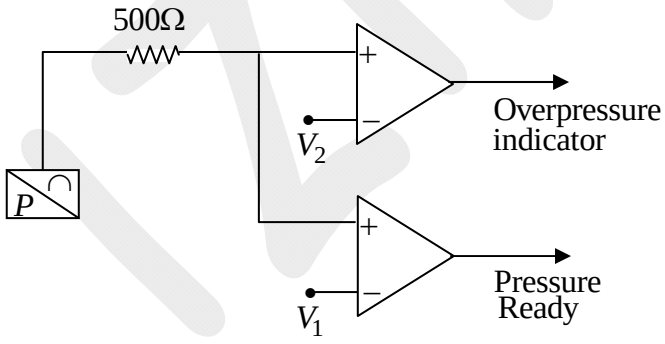
Q54. A perfectly conducting fluid of permittivity ε and permeability μ flows with a uniform velocity $\vec{v}$ in the presence of time dependent electric and magnetic fields $\vec{E}$ and $\vec{B}$, respectively, if there is a finite current density in the fluid, then

(a) $\vec{\nabla} \times (\vec{v} \times \vec{B}) = \dfrac{\partial \vec{B}}{\partial t}$ (b) $\vec{\nabla} \times (\vec{v} \times \vec{B}) = -\dfrac{\partial \vec{B}}{\partial t}$

(c) $\vec{\nabla} \times (\vec{v} \times \vec{B}) = \sqrt{\varepsilon\mu}\dfrac{\partial \vec{E}}{\partial t}$ (d) $\vec{\nabla} \times (\vec{v} \times \vec{B}) = -\sqrt{\varepsilon\mu}\dfrac{\partial \vec{E}}{\partial t}$

Ans. 54: (a)

Q55. The pressure of a gas in a vessel needs be maintained between 1.5 bar to 2.5 bar in an experiment. The vessel is fitted with a pressure transducer that generates $4\,mA$ to $20\,mA$ current for pressure in the range 1 bar to 5 bar. The current output of the transducer has a linear dependence on the pressure.



The reference voltages V_1 and V_2 in the comparators in the circuit (shown in figure above) suitable for the desired operating conditions are respectively

(a) $2V$ and $10V$ (b) $2V$ and $5V$ (c) $3V$ and $10V$ (d) $3V$ and $5V$

Ans. 55: (d)

Q56. The energy levels of a non-degenerate quantum system are $\in_n = nE_0$, where E_0 is a constant and $n = 1, 2, 3, \ldots$. At a temperature T, the free energy F can be expressed in terms of the average energy E by

(a) $E_0 + k_B T \ln \dfrac{E}{E_0}$ (b) $E_0 + 2k_B T \ln \dfrac{E}{E_0}$ (c) $E_0 - k_B T \ln \dfrac{E}{E_0}$ (d) $E_0 - 2k_B T \ln \dfrac{E}{E_0}$

Ans. 56: (c)

Q57. A particle in two dimensions is found to trace an orbit $r(\theta)=r_0\theta^2$. If it is moving under the influence of a central potential $V(r)=c_1r^{-a}+c_2r^{-b}$, where r_0, c_1 and c_2 are constants of appropriate dimensions, the values of a and b, respectively, are

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

Ans. 57: (b)

Q58. A particle of mass m moves in a potential that is $V=\frac{1}{2}m\left(\omega_1^2x^2+\omega_2^2y^2+\omega_3^2z^2\right)$ in the coordinates of a non-inertial frame F. The frame F is rotating with respect to an inertial frame with an angular velocity $\hat{k}\Omega$, where $\hat{k}$ it is the unit vector along their common z-axis. The motion of the particle is unstable for all angular frequencies satisfying

(a) $\left(\Omega^2-\omega_1^2\right)\left(\Omega^2-\omega_2^2\right)>0$ (b) $\left(\Omega^2-\omega_1^2\right)\left(\Omega^2-\omega_2^2\right)<0$

(c) $\left(\Omega^2-\left(\omega_1+\omega_2\right)^2\right)\left(\Omega^2-\left|\omega_1-\omega_2\right|^2\right)>0$ (d) $\left(\Omega^2-\left(\omega_1+\omega_2\right)^2\right)\left(\Omega^2-\left|\omega_1-\omega_2\right|^2\right)<0$

Ans. 58: (b)

Q59. A ^{60}Co nucleus β-decays from its ground state with $J^P=5^+$ to a state of ^{60}Ni with $J^P=4^+$. From the angular momentum selection rules, the allowed values of the orbital angular momentum L and the total spin S of the electron-antineutrino pair are

(a) $L=0$ and $S=1$ (b) $L=1$ and $S=0$ (c) $L=0$ and $S=0$ (d) $L=1$ and $S=1$

Ans. 59: (a)

Q60. A satellite of mass m orbits around earth in an elliptic trajectory of semi-major axis a. At a radial distance $r=r_0$, measured from the centre of the earth, the kinetic energy is equal to half the magnitude of the total energy. If M denotes the mass of the earth and the total energy is $-\frac{GMm}{2a}$, the value of r_0/a is nearest to

(a) 1.33 (b) 1.48 (c) 1.25 (d) 1.67

Ans. 60: (a)

Q61. A particle of mass m in one dimension is in the ground state of a simple harmonic oscillator described by a Hamiltonian $H=\frac{p^2}{2m}+\frac{1}{2}m\omega^2x^2$ in the standard notation. An impulsive force at time to $t=0$ suddenly imparts a momentum $p_0=\sqrt{\hbar m\omega}$ to it. The probability that the particle remains in the original ground state is

(a) e^{-2} (b) $e^{-3/2}$ (c) e^{-1} (d) $e^{-1/2}$

Ans. 61: (d)

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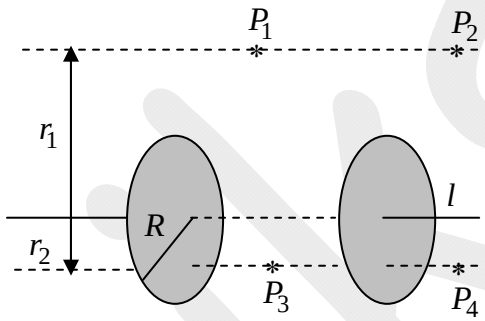
Q62. A polymer, made up of N monomers, is in thermal equilibrium at temperature T. Each monomer could be of length a or $2a$. The first contributes zero energy, while the second one contributes $\in$. The average length (in units of Na) of the polymer at temperature $T = \in / k_B$ is

(a) $\frac{5+e}{4+e}$ (b) $\frac{4+e}{3+e}$ (c) $\frac{3+e}{2+e}$ (d) $\frac{2+e}{1+e}$

Ans. 62: (d)

Q63. The figure below shows an ideal capacitor consisting of two parallel circular plates of radius R. Points P_1 and P_2 are at a transverse distance, $r_1 > R$ from the line joining the centers of the plates, while points P_3 and P_4 are at a transverse distance $r_2 < R$.



It $B(x)$ denotes the magnitude of the magnetic fields at these points, which of the following holds while the capacitor is charging?

(a) $B(P_1) < B(P_2)$ and $B(P_3) < B(P_4)$ (b) $B(P_1) > B(P_2)$ and $B(P_3) > B(P_4)$

(c) $B(P_1) = B(P_2)$ and $B(P_3) < B(P_4)$ (d) $B(P_1) = B(P_2)$ and $B(P_3) > B(P_4)$

Ans. 63: (c)

Q64. The $|3,0,0\rangle$ state in the standard notation $|n,l,m\rangle$ of the H-atom in the non-relativistic theory decays to the state $|1,0,0\rangle$ via two dipole transition. The transition route and the corresponding probability are

(a) $|3,0,0\rangle \to |2,1,-1\rangle \to |1,0,0\rangle$ and $1/4$ (b) $|3,0,0\rangle \to |2,1,1\rangle \to |1,0,0\rangle$ and $1/4$

(c) $|3,0,0\rangle \to |2,1,0\rangle \to |1,0,0\rangle$ and $1/3$ (d) $|3,0,0\rangle \to |2,1,0\rangle \to |1,0,0\rangle$ and $2/3$

Ans. 64: (c)

Q65. Balls of ten different colours labeled by $a = 1,2,...,10$ are to be distributed among different coloured boxes. A ball can only go in a box of the same colour, and each box can contain at most one ball. Let n_a and N_a denote respectively, the numbers of balls and boxes of colour a. Assuming that $N_a >> n_a >> 1$, the total entropy (in units of the Boltzmann constant) can be best approximated by

(a) $\sum_a \left(N_a \ln N_a + n_a \ln n_a - \left(N_a - n_a\right)\ln\left(N_a - n_a\right)\right.$

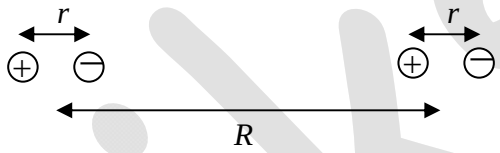
(b) $\sum_a \left(N_a \ln N_a - n_a \ln n_a + \left(N_a - n_a\right)\ln\left(N_a - n_a\right)\right)$

(c) $\sum_a \left(N_a \ln N_a - n_a \ln n_a + \left(N_a - n_a\right)\ln\left(N_a - n_a\right)\right)$

(d) $\sum_a \left(N_a \ln N_a + n_a \ln n_a + \left(N_a - n_a\right)\ln\left(N_a - n_a\right)\right)$

Ans. 65: (b)

Q66. A linear diatomic molecule consists of two identical small electric dipoles with an equilibrium separation R, which is assumed to be a constant. Each dipole has charges $\pm q$ of mass m separated by r when the molecule is at equilibrium. Each dipole can execute simple harmonic motion of angular frequency ω



Recall that the interaction potential between two dipoles of moments $\vec{p}_1$ and $\vec{p}_2$, separated by $\vec{R}_{12} = R_{12}\hat{n}$ is $\left(\vec{p}_1 \cdot \vec{p}_2 - 3\left(\vec{p}_1 \cdot \hat{n}\right)\left(\vec{p}_2 \cdot \hat{n}\right)/\left(4\pi \in_0 R_{12}^3\right)\right.$.

Assume that $R \gg r$ and let $\Omega^2 = \dfrac{q^2}{4\pi \in_0 mR^3}$. The angular frequencies of small oscillations of the diatomic molecule are

(a) $\sqrt{\omega^2 + \Omega^2}$ and $\sqrt{\omega^2 - \Omega^2}$

(b) $\sqrt{\omega^2 + 3\Omega^2}$ and $\sqrt{\omega^2 - 3\Omega^2}$

(c) $\sqrt{\omega^2 + 4\Omega^2}$ and $\sqrt{\omega^2 - 4\Omega^2}$

(d) $\sqrt{\omega^2 + 2\Omega^2}$ and $\sqrt{\omega^2 - 2\Omega^2}$

Ans. 66: (c)

Q67. The Legendre polynomials $P_n(x), n = 0,1,2,...,$ satisfying the orthogonality condition $\int_{-1}^{1} P_n(x)\, p_m(x)\, dx = \dfrac{2}{2n+1}\delta_{nm}$ on the interval $[-1,+1]$, may be defined by the Rodrigues formula $P_n(x) = \dfrac{1}{2^n n!}\dfrac{d^n}{dx^n}\left(x^2 - 1\right)^n$. The value of the definite integral $\int_{-1}^{1}\left(4 + 2x - 3x^2 + 4x^3\right)P_3(x)\, dx$ is

(a) $3/5$ (b) $11/15$ (c) $23/32$ (d) $16/35$

Ans. 67: (d)

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Q68. If we use the Fourier transform $\phi(x,y)=\int e^{ikx}\phi_k(y)dk$ to solve the partial differential equation $-\frac{\partial^2\phi(x,y)}{\partial y^2}-\frac{1}{y^2}\frac{\partial^2\phi(x,y)}{\partial x^2}+\frac{m^2}{y^2}\phi(x,y)=0$ in the half-plane $\{(x,y):-\infty<x<\infty,0<y<\infty\}$ the Fourier modes $\phi_k(y)$ depend on y as y^α and y^β. The value of α and β are

(a) $\frac{1}{2}+\sqrt{1+4\left(k^2+m^2\right)}$ and $\frac{1}{2}-\sqrt{1+4\left(k^2+m^2\right)}$

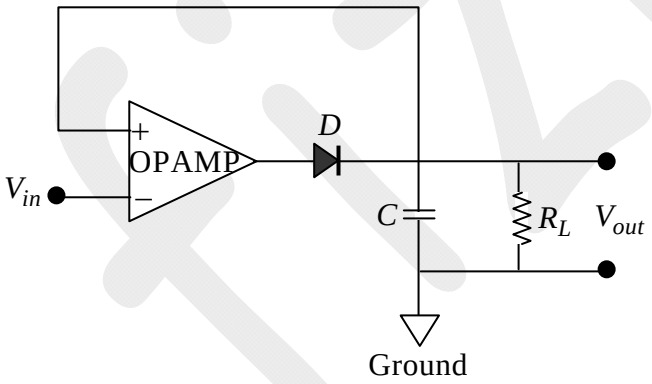
(b) $1+\sqrt{1+4\left(k^2+m^2\right)}$ and $1-\sqrt{1+4\left(k^2+m^2\right)}$

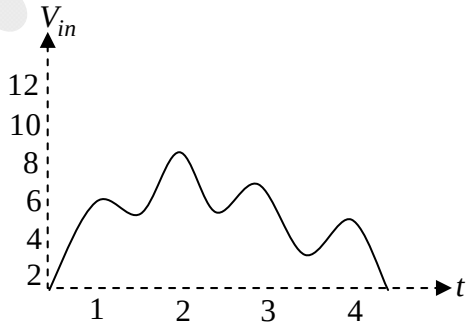
(c) $\frac{1}{2}+\frac{1}{2}\sqrt{1+4\left(k^2+m^2\right)}$ and $\frac{1}{2}-\frac{1}{2}\sqrt{1+4\left(k^2+m^2\right)}$

(d) $1+\frac{1}{2}\sqrt{1+4\left(k^2+m^2\right)}$ and $1-\frac{1}{2}\sqrt{1+4\left(k^2+m^2\right)}$

Ans. 68: (c)

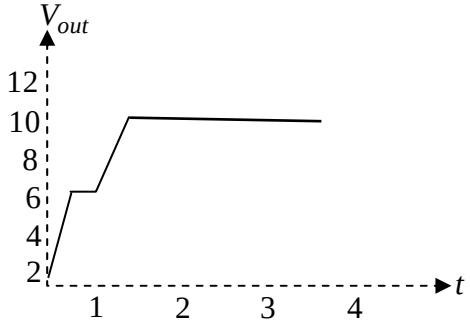
Q69. In the following circuit the input voltage V_{in} is such that $|V_{in}|<|V_{sat}|$ where V_{sat} is the saturation voltage of the op-amp (Assume that the diode is an ideal one and R_LC is much larger than the duration of the measurement.)



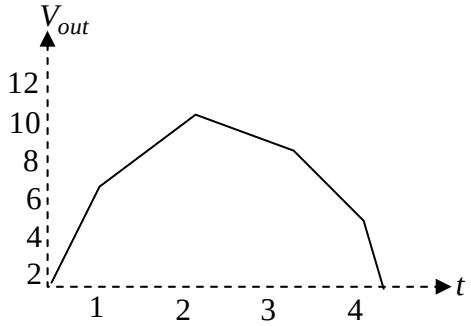


For the input voltage as shown in the figure above the output voltage V_{out} is best represented by

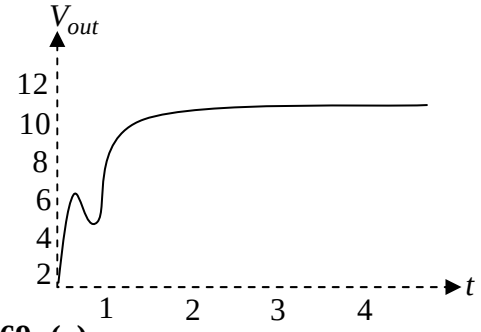
(a)



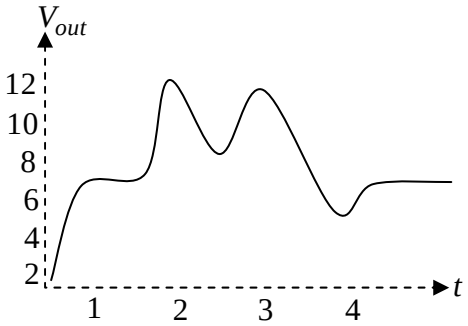
(b)



(c)



(d)



Ans. 69: (a)

Q70. Potassium chloride forms an FCC lattice, in which K and Cl occupy alternating sites. The density of KCl is $1.98\,g/cm^3$ and the atomic weights of K and Cl are 39.1 and 35.5, respectively. The angles of incidence (in degrees) for which Bragg peaks will appear when X-ray of wavelength $0.4\,nm$ is shone on a KCl crystal are

(a) 18.5, 39.4 and 72.2 (b) 19.5 and 41.9

(c) 12.5, 25.7, 40.5 and 60.0 (d) 13.5, 27.8, 44.5 and 69.0

Ans. 70: (a)

Q71. Lead is superconducting below $7K$ and has a critical magnetic field 800×10^{-4} tesla close to $0\,K$. At $2\,K$ the critical current that flows through a long lead wire of radius $5\,mm$ is closest to

(a) $1760\,A$ (b) $1670\,A$ (c) $1950\,A$ (d) $1840\,A$

Ans. 71: (d)

Q72. The Q-value of the α-decay of ^{232}Th to the ground state of ^{228}Ra in $4082\,keV$. The maximum possible kinetic energy of the α-particle is closest to

(a) $4082\,keV$ (b) $4050\,keV$ (c) $4035\,keV$ (d) $4012\,keV$

Ans. 72: (d)

Q73. In the reaction $p+n\rightarrow p+K^{+}+X$ mediated by strong interaction, the baryon number B, strangeness S and the third component of isospin I_3 of the particle X are, respectively

(a) $-1,-1$ and -1 (b) $+1,-1$ and -1 (c) $+1,-2$ and $-\frac{1}{2}$ (d) $-1,-1$ and 0

Ans. 73: (b)

Q74. In an elastic scattering process at an energy E, the phase shifts satisfy $\delta_0\approx30^{\circ},\delta_1\approx10^{\circ}$, while the other phase shifts are zero. The polar angle at which the differential cross section peaks is closest to

(a) 20° (b) 10° (c) 0° (d) 30°

Ans. 74: (c)

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Q75. The unnormalized wave function of a particle in one dimension in an infinite square well with walls at $x=0$ and $x=a$, is $\psi(x)=x(a-x)$. If $\psi(x)$ is expanded as a linear combination of the energy eigenfunctions, $\int_0^a |\psi(x)|^2\,dx$ is proportional to the infinite series

(You may use $\int_0^a t\sin t\,dt=-a\cos a+\sin a$ and $\int_0^a t^2\sin t\,dt=-2-(a^2-2)\cos a+2a\sin a$

(a) $\sum_{n=1}^{\infty}(2n-1)^{-6}$ (b) $\sum_{n=1}^{\infty}(2n-1)^{-4}$ (c) $\sum_{n=1}^{\infty}(2n-1)^{-2}$ (d) $\sum_{n=1}^{\infty}(2n-1)^{-8}$

Ans. 75: (a)

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NIT, Kurukshetra

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JEST AIR - 211,
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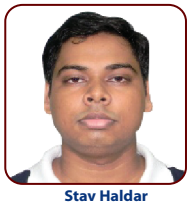

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