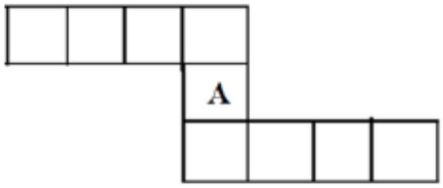
NET-JRF June 2022

PART A

Question ID:- 515

The squares in the following sketch are filled with digits 1 to 9, without any repetition, such that the numbers in the

two horizontal rows add up to 20 each. What number appears in the square labelled A in the vertical column?



It cannot be ascertained in the absence of the sum of the numbers in the column , Option ID :- 2057,

3, Option ID :- 2058,

5, Option ID :- 2059,

7, Option ID :- 2060,

Question ID:- 516

Sections A, B, C and D of a class have 24, 27, 30 and 36 students, respectively. One section has boys and girls who

are seated alternately in three rows, such that the first and the last positions in each row are occupied by boys. Which

section could this be?

A, Option ID :- 2061,

B, Option ID :- 2062,

C, Option ID :- 2063,

D, Option ID :- 2064,

Question ID:- 517

In a round-robin tournament, after each team has played exactly four matches, the number of wins/ losses of 6 participating teams are as follows

Team	Win	Loss
A	4	0
B	0	4
C	3	1
D	2	2
E	0	4
F	3	1

Which of the two teams have certainly NOT played with each other?

A and B, Option ID :- 2065,

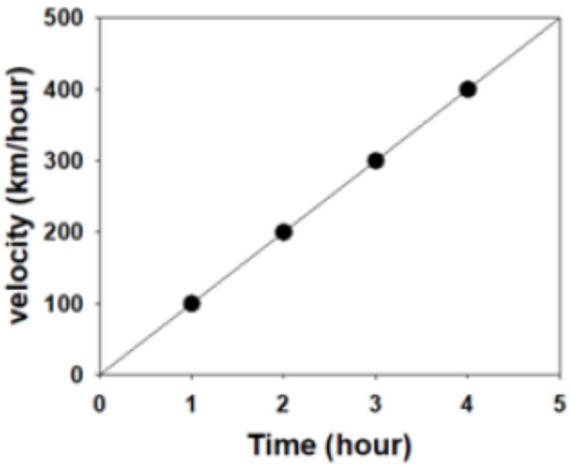
C and F, Option ID :- 2066,

E and D, Option ID :- 2067,

B and E, Option ID :- 2068

Question ID:- 518

Given plot describes the motion of an object with time.



Which one of the following statements is CORRECT?

The object is moving with a constant velocity, Option ID :- 2069,

The object covers equal distance every hour, Option ID :- 2070,

The object is accelerating, Option ID :- 2071,

Velocity of the object doubles every hour, Option ID :- 2072

Question ID:- 519

If one letter each is drawn at random from the words CAUSE and EFFECT, the chance that they are the same is

1/30 , Option ID :- 2073,

1/11 , Option ID :- 2074,

1/10 , Option ID :- 2075,

2/11, Option ID :- 2076,

Question ID:- 520

A vehicle has tyres of diameter 1 m connected by a shaft directly to gearwheel A which meshes with gearwheel B as shown in the diagram. A has 12 teeth and B has 8. If points *x* on A and *y* on B are initially in contact, they will again be in contact after the vehicle has travelled a distance (in meters)

2π, Option ID :- 2077,

3π, Option ID :- 2078,

4π, Option ID :- 2079,

12π, Option ID :- 2080

Question ID:- 521

A liar always lies and a non-liar, never. If in a group of *n* persons seated around a round-table everyone calls his/her left neighbor a liar, then

all are liars, Option ID :- 2081,

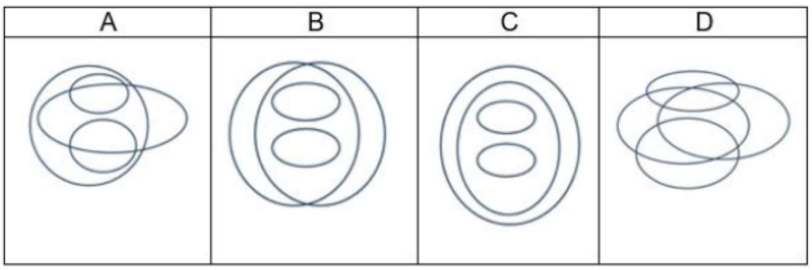
n must be even and every alternate person is a liar, Option ID :- 2082,

n must be odd and every alternate person is a liar, Option ID :- 2083,

n must be a prime, Option ID :- 2084

Question ID:- 522

The correct pictorial representation of the relations among the categories PLAYERS, FEMALE CRICKETERS, MALE FOOTBALLERS and GRADUATES is



A, Option ID :- 2085,

B, Option ID :- 2086,

C, Option ID :- 2087,

D, Option ID :- 2088

Question ID:- 523

What is the product of the number of capital letters and the number of small letters of the English alphabet in the

following text?

17, Option ID :- 2089,

37, Option ID :- 2090,

53, Option ID :- 2091,

63, Option ID :- 2092,

Question ID:- 524

On a track of 200 m length, S runs from the starting point and R starts 20 m ahead of S at the same time. Both reach the end of the track at the same time. S runs at a uniform speed of 10 m/s. If R also runs at a uniform speed, what is R's speed (in m/s)?

9, Option ID :- 2093,

10, Option ID :- 2094,

12, Option ID :- 2095,

8, Option ID :- 2096,

Question ID:- 525

A plant grows by 10% of its height every three months. If the plant's height today is 1 m, its height after one year is

the closest to

1.10 m, Option ID :- 2097,

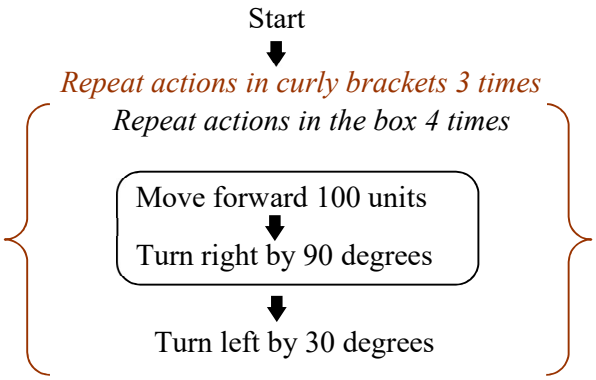
1.21 m, Option ID :- 2098,

1.33 m, Option ID :- 2099,

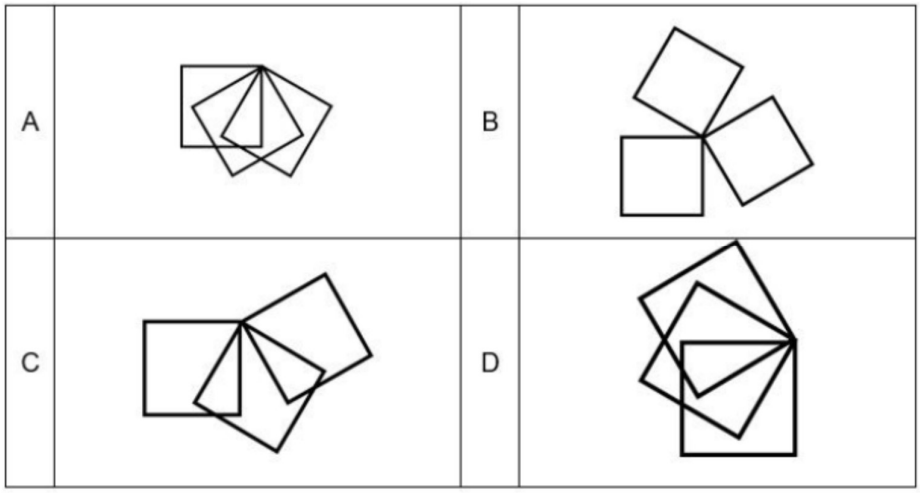
1.46 m, Option ID :- 2100,

Question ID:- 526

Starting from the top of a page and pointing downward, an ant moves according to the following commands



Of the following paths



Which is the current path of the ant?

Options:-

A, Option ID :- 2101,

B, Option ID :- 2102,

C, Option ID :- 2103,

D, Option ID :- 2104

Question ID:- 527

In a four-digit PIN, the third digit is the product of the first two digits and the fourth digit is zero. The number of such

PINs is

42, Option ID :- 2105,

41, Option ID :- 2106,

40, Option ID :- 2107,

39, Option ID :- 2108,

Question ID:- 528

After 10:00:00 the hour hand and minute hand of a clock will be perpendicular to each other for the first time at

12:16:21, Option ID :- 2109,

12:15:00, Option ID :- 2110,

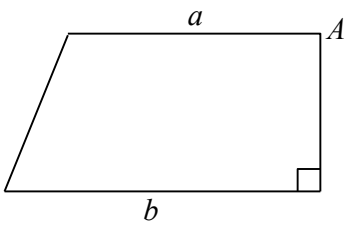
13:22:21, Option ID :- 2111,

12:48:08, Option ID :- 2112

Question ID:- 529

At what horizontal distance from A should a vertical line be drawn so as to divide the area of the trapezium shown in

the figure into two equal parts ? (a and b are lengths of the parallel sides.)



$(a+b)/4$, Option ID :- 2113,

$(a+b)/3$, Option ID :- 2114,

$(a+b)/2$, Option ID :- 2115,

$(2a+b)/2$, Option ID :- 2116,

Question ID:- 530

I have a brother who is 4 years elder to me, and a sister who was 5 years old when my brother was born. When my sister was born, my father was 24 years old. My mother was 27 years old when I was born. How old (in years) were my father and mother, respectively, when my brother was born?

29 and 23, Option ID :- 2117,

27 and 25, Option ID :- 2118,

27 and 23, Option ID :- 2119,

29 and 25, Option ID :- 2120

Question ID:- 531

A boy has kites of which all but 9 are red, all but 9 are yellow, all but 9 are green, and all but 9 are blue. How many kites does he have?

2, Option ID :- 2121,

15, Option ID :- 2122,

9, Option ID :- 2123,

18, Option ID :- 2124

Question ID:- 532

Tokens numbered from 1 to 25 are mixed and one token is drawn randomly. What is the probability that the number on the token drawn is divisible either by 4 or by 6?

8/25, Option ID: 2125

10/25, Option ID: 2126

9/25, Option ID: 2127

12/25, Option ID: 2128

Question ID:- 533

A beam of square cross-section is to be cut out of a wooden log. Assuming that the log is cylindrical, what approximately is the largest fraction of the wood by volume that can be fruitfully utilized as the beam?

49%, Option ID :- 2129,

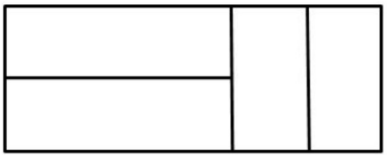
64%, Option ID :- 2130,

71%, Option ID :- 2131,

81%, Option ID :- 2132

Question ID:- 534

How many rectangles are there in the given figure?



6, Option ID :- 2133,

7, Option ID :- 2134,

8, Option ID :- 2135,

9, Option ID :- 2136

PART B

Question ID:- 1

The value of the integral $\int_0^\infty dx e^{-x^{2m}}$, where m is a positive integer, is

Options:-

$\Gamma\left(\frac{m+1}{2m}\right)$, Option ID :- 1,

$\Gamma\left(\frac{m-1}{2m}\right)$, Option ID :- 2,

$\Gamma\left(\frac{2m+1}{2m}\right)$, Option ID :- 3,

$\Gamma\left(\frac{2m-1}{2m}\right)$, Option ID :- 4,

Topic – Mathematical Physics

Subtopic – Integration

Question ID:- 2

At $z = 0$, the function $\frac{1}{z-\sin z}$ of a complex variable z has

Options:

No singularity , Option ID: 5

A simple pole , Option ID: 6

A pole of order 2 , Option ID: 7

A pole of order 3 , Option ID: 8

Topic – Mathematical Physics

Subtopic – Complex Analysis

Question ID:- 3

Two $n \times n$ invertible real matrices A and B satisfy the relation

$$(AB)^T = -(A^{-1}B)^{-1}$$

If B is orthogonal then A must be

Options:

Lower triangle; Option ID : 9

Orthogonal; Option ID : 10

Symmetric; Option ID : 11

Anti-Symmetric; Option ID : 12

Topic – Mathematical Physics

Subtopic – Matrices

Question ID:- 4

The infinite series $\sum_{n=0}^{\infty}(n^2+3n+2)x^n$ evaluated at $x=\frac{1}{2}$, is

Options:

16; Option ID: 13

32; Option ID: 14

8; Option ID: 15

24; Option ID: 16

Topic – Mathematical Physics

Subtopic – Series

Question ID:- 5

If $z=i^{i^{i^{\cdots\cdots}}}$ (note that the exponent continues indefinitely), then a possible value of $\frac{1}{z}\ln\ z$ is

Options:-

$2i\ln\ i$, Option ID :- 17,

$\ln\ i$, Option ID :- 18,

$i\ln\ i$,Option ID :- 19,

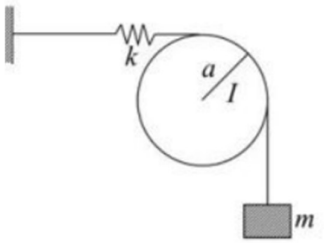
$2\ln\ i$ Option ID :- 20,

Topic – Mathematical Physics

Subtopic – Complex Analysis

Question ID:- 6

A wire, connected to a massless spring of spring constant k and a block of mass m, goes around a disc of radius a and moment of inertia I, as shown in the figure.



Assume that the spring remains horizontal, the pully rotates freely and there is no slippage between the wire and the pully. The angular frequency of oscillation of the disc is

Options:-

$\sqrt{\frac{2ka^2}{ma^2+I}}$, Option ID:- 21

$\sqrt{\frac{ka^2}{ma^2+I}}$, Option ID:- 22

$\sqrt{\frac{ka^2}{ma^2+2I}}$, Option ID :- 23,

$\sqrt{\frac{ka^2}{2ma^2+I}}$, Option ID:- 24

Topic –Classical Mechanics

Subtopic – Rotational Motion

Question ID:- 7

The Lagrangian of a system described by three generalized coordinates q_1, q_2 and q_3 is $L = \frac{1}{2}m(\dot{q}_1^2 + \dot{q}_2^2) + M\dot{q}_1\dot{q}_2 + k\dot{q}_1 q_3$, where m, M and k are positive constants. Then, as a function of time

Options:

Two coordinates remain constant and one evolves linearly; Option ID: 25

One coordinates remain constant, one evolves linearly and Third evolves as a quadratic function; Option ID: 26

One evolves linearly and Two evolves as a quadratic function; Option ID: 27

Al three evolves linearly; Option ID: 28

Topic – Classical Mechanics

Subtopic – Lagrangian Formulation

Question ID:- 8

The periods of oscillation of a simple pendulum at the sea level and at the top of a mountain of height $6\ \text{km}$ are T_1 and T_2, respectively. If the radius of earth is approximately $6000\ \text{km}$, then $\frac{(T_2 - T_1)}{T_1}$ is closest to

Options:-

-10^{-4}, Option ID :- 29,

-10^{-3}, Option ID :- 30,

10 , Option ID :- 31,

10^{-3}, Option ID :- 32

Topic – Classical Mechanics

Subtopic – Gravitation

Question ID:- 9

A particle of rest mass m is moving with a velocity $v\hat{k}$, with respect to an inertial frame S. The energy of the particle as measured by an observer S', who is moving with a uniform velocity $u\hat{1}$ with respect to S (in terms of $\gamma_u = 1/\sqrt{1 - u^2/c^2}$ and $\gamma_v = 1/\sqrt{1 - v^2/c^2}$) is

Options:

$\gamma_u\gamma_v m(c^2 - uv)$, Option ID :- 33,

$\gamma_u\gamma_v mc^2$, Option ID :- 34,

$\frac{1}{2}(\gamma_u + \gamma_v)mc^2$, Option ID :- 35,

$\frac{1}{2}(\gamma_u + \gamma_v)m(c^2 - uv)$, Option ID :- 36,

Topic – Classical Mechanics

Subtopic – STR

Question ID:- 10

An electromagnetic wave is incident from vacuum normally on a planar surface of a non-magnetic medium. If the amplitude of the electric field of the incident wave is E_0 and that of the transmitted wave is $2E_0/3$, then neglecting any loss, the refractive index of the medium is

Options:-

1.5, Option ID:- 37

2.0, Option ID:- 38

2.4, Option ID:- 39

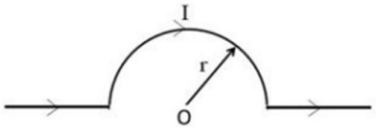
2.7, Option ID:- 40

Topic – Electromagnetic Theory

Subtopic – Electromagnetic Wave

Question ID:- 11

A part of an infinitely long wire, carrying a current I, is bent in a semicircular arc of radius r (as shown in the figure). The magnetic field at the centre O of the arc is



Options:-

$\frac{\mu_0 I}{4r}$, Option ID:- 41,

$\frac{\mu_0 I}{4\pi r}$, Option ID:- 42,

$\frac{\mu_0 I}{2r}$, Option ID:- 43,

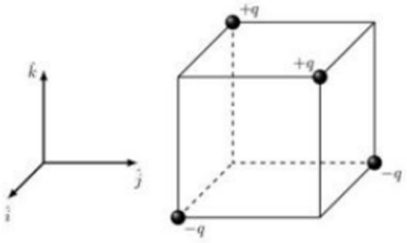
$\frac{\mu_0 I}{2\pi r}$, Option ID :- 44,

Topic – Electromagnetic Theory

Subtopic – Magnetostatics / Ampere's Circuital Law

Question ID:- 12

Two positive and two negative charges of magnitude q are placed on the alternate vertices of a cube of side a (as shown in the figure). The electric dipole moment of this charge configuration is



Options:-

$-2qa\hat{\mathbf{k}}$ Option ID : – 45,

$2qa\hat{\mathbf{k}}$ Option ID : – 46,

$2qa(\hat{\mathbf{i}}+\hat{\mathbf{j}})$, Option ID :- 47,

$2qa(\hat{\mathbf{i}}-\hat{\mathbf{j}})$Option ID : – 48

Topic – Electromagnetic Theory

Subtopic –Multipole Expansion

Question ID:- 13

The electric and magnetic fields in an inertial frame are $\mathbf{E} = 3a\hat{\mathbf{i}} - 4\hat{j}$ and $\mathbf{B} = \frac{5a}{c}\hat{\mathbf{k}}$, where a is a constant. A massive charged particle is released from rest. The necessary and sufficient condition that there is an inertial frame, where the trajectory of the particle is a uniform-pitched helix, is

Options:-

$1 < a < \sqrt{2}$, Option ID :- 49,

$-1 < a < 1$, Option ID :- 50,

$a^2 > 1$, Option ID :- 51,

$a^2 > 2$, Option ID :- 52,

Topic – Electromagnetic Theory

Subtopic – Relativistic Electrodynamics

Question ID:- 14

If the expectation value of the momentum of a particle in one dimension is zero, then its (box-normalizable) wavefunction may be of the form

Options:-

$\sin\ kx$, Option ID :- 53,

$e^{ikx}\sin\ kx$, 0ption ID :- 54,

$e^{ikx}\cos\ kx$, Option ID :- 5S,

$\sin\ kx + e^{ikx}\cos\ kx$., Option ID :- 56

Topic – Quantum Mechanics

Subtopic – Particle in Box

Question ID:- 15

In terms of a complete set of orthonormal basis kets $|n\rangle$, $n = 0, \pm1, \pm2, \cdots$, the Hamiltonian is

$$H = \sum_n \left(E|n\rangle\langle n| + \epsilon|n+1\rangle\langle n| + \epsilon|n\rangle\langle n+1|\right)$$

where E and ϵ are constants. The state $|\varphi\rangle = \sum_n e^{in\varphi}|n\rangle$ is an eigenstate with energy

Options:-

$E + \epsilon\cos\varphi$, Option ID : − 57,

$E - \epsilon\cos\varphi$, Option ID : − 58,

$E + 2\epsilon\cos\varphi$, Option ID : − 59,

$E - 2\epsilon\cos\varphi$, Option ID : − 60

Topic – Quantum Mechanics

Subtopic – Energy Eigen Value

Question ID:- 16

The momentum space representation of the Schrödinger equation of a particle in a potential $V(\vec{r})$ is $\left(|\mathbf{p}|^2 + \beta\left(\nabla_p^2\right)^2\right)\psi(\mathbf{p},t) = i\hbar\frac{\partial}{\partial t}\psi(\mathbf{p},t)$, where $\left(\boldsymbol{\nabla}_p\right)_i = \frac{\partial}{\partial p_i}$, and β is a constant. The potential is (in the following V_0 and a are constants)

Options:-

$V_0 e^{-r^2/a^2}$ Option ID :- 61,

$V_0 e^{-r^4/a^4}$ Option ID :- 62,

$V_0\left(\frac{r}{a}\right)^2$, Option ID :- 63,

$V_0\left(\frac{r}{a}\right)^4$, Option ID :- 64,

Topic – Quantum Mechanics

Subtopic – Relativistic Quantum Mechanics

Question ID:- 17

Consider the Hamiltonian $H = AI + B\sigma_x + C\sigma_y$, where A, B and C are positive constants, I is the 2×2 identity matrix and σ_x, σ_y are Pauli matrices. If the normalized eigenvector corresponding to its largest energy eigenvalue is $\frac{1}{\sqrt{2}}\begin{pmatrix}1\\ y\end{pmatrix}$, then y is

Options:-

$\frac{B+iC}{\sqrt{B^2+C^2}}$, Option ID : − 65, $\frac{A-iB}{\sqrt{A^2+B^2}}$, Option ID : − 66,

$\frac{A-iC}{\sqrt{A^2+C^2}}$, Option ID : − 67, $\frac{B-iC}{\sqrt{B^2+C^2}}$, Option ID : − 68

Topic – Quantum Mechanics

Subtopic – Spin Angular Momentum

Question ID:- 18

If the average energy $\langle E\rangle_T$ of a quantum harmonic oscillator at a temperature T is such that $\langle E\rangle_T = 2\langle E\rangle_{T\to 0}$, then T satisfies

Options:-

$\coth\left(\frac{\hbar\omega}{k_B T}\right) = 2$, Option ID : − 69, $\coth\left(\frac{\hbar\omega}{2k_B T}\right) = 2$, Option ID : − 70,

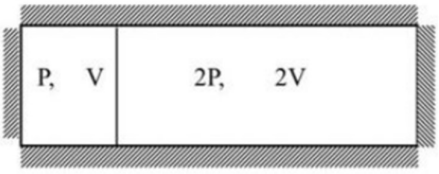
$\coth\left(\frac{\hbar\omega}{k_B T}\right) = 4$, Option ID : − 71, $\coth\left(\frac{\hbar\omega}{2k_B T}\right) = 4$, Option ID : − 72,

Topic – Statistical Mechanics

Subtopic – Partition Function

Question ID:- 19

A thermally isolated container, filled with an ideal gas at temperature T, is divided by a partition, which is clamped initially, as shown in the figure below.



The partition does not allow the gas in the two parts to mix. It is subsequently released and allowed to move freely with negligible friction . The final pressure at equilibrium is

Options:

5P/3, Option ID:73,

5P/4, Option ID:74

3P/5, Option ID:75,

4P/5, Option ID:75

Topic – Thermodynamics & Statistical Mechanics

Subtopic – Thermodynamic Process

Question ID:- 20

A walker takes steps, each of length L, randomly in the directions along east, west, north and south. After four steps its distance from the starting point is d. The probability that $d \leq 3L$ is

Options

63/64, Option ID: 77,

59/64, Option ID: 78

57/64, Option ID: 79,

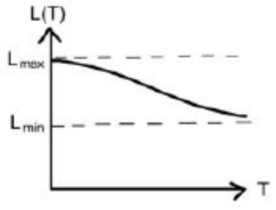
55/64, Option ID: 80

Topic – Statistical Mechanics

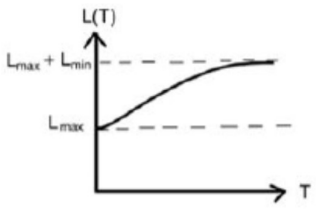
Subtopic – Random Walk Problem

Question ID:- 21

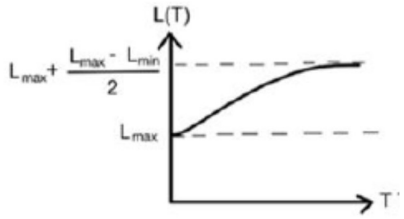
An elastic rod has a low energy state of length $L_{\max}$ and high energy state of length $L_{\min.}$. The best schematic representation of the temperature (T) dependence of the mean equilibrium length $L(T)$ of the rod, is



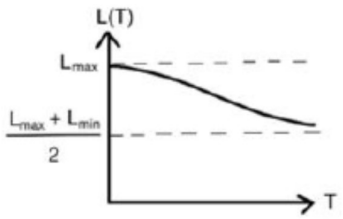
Option ID :- 81



Option ID :- 82



Option ID :- 83



Option ID :- 84

Topic – Thermodynamics & Statistical Mechanics

Subtopic – Thermodynamics Equilibrium

Question ID:- 22

The circuit containing two n-channel MOSFETs shown below, works as

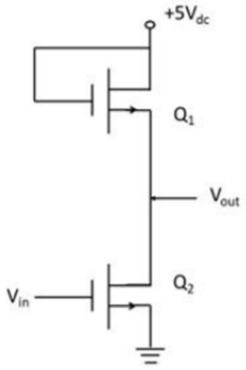
Options:-

a buffer, Option ID :- 85,

a non-inverting amplifier, Option ID :- 86,

an inverter, Option ID :- 87 ,

a rectifier, Option ID :- B8,

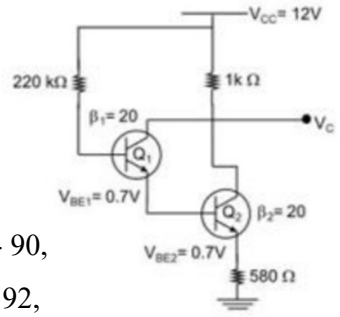


Topic – Electronics

Subtopic – MOSFET

Question ID:- 23

The figure below shows a circuit with two transistors, Q_1 and Q_2, having current gains β_1 and β_2 respectively. The collector voltage V_C will be closest to



Options:-

0.9 V, Option ID :- 89,

2.2 V , Option ID :- 90,

2.9 V, Option ID :- 91,

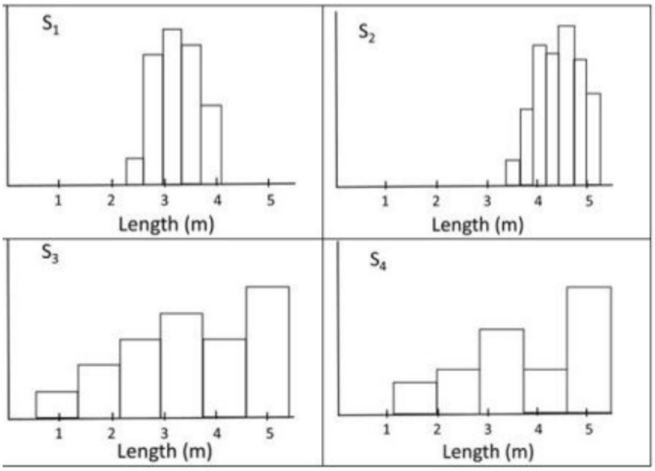
4.2 V, Option ID :- 92,

Topic – Electronics

Subtopic – Transistor

Question ID:- 24

Four students (S_1, S_2, S_3 and S_4) make multiple measurements on the length of a table. The binned data are plotted as histograms in the following figures



Options:

S_2, Option ID :- 93,

S_1, Option ID :- 94

S_4, Option ID :- 95,

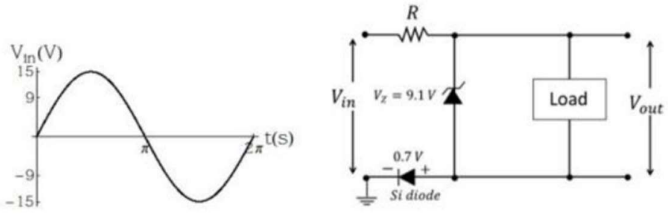
S, Option ID :- 96

Topic – Mathematical Physics

Subtopic – Probability

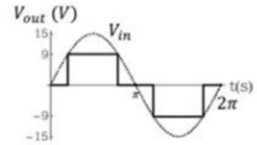
Question ID:- 25

A high impedence load network is connected in the circuit as shown below

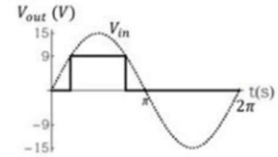


The forward voltage drop for silicon diode is 0.7 V and the Zener voltage is 9.10 V. If the input voltage (V_{in}) is sine wave with an amplitude of 15 V (as shown in the figure above), which of the following waveform qualitatively describes the output voltage (V_{out}) across the load?

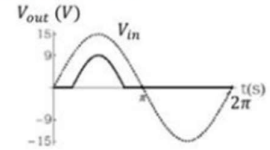
Options:-



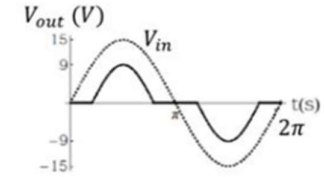
Option ID :- 97,



Option ID :- 98,



Option ID :- 99,



Option ID :- 100,

Topic – Electronics

Subtopic – Zener Diode

Question ID:- 26

A bucket contains 6 red and 4 blue balls. *A* ball is taken out of the bucket at random and two balls of the same colour are put back. This step is repeated once more. The probability that the numbers of red and blue balls are equal at the end, is

Options:

4/11, Option ID: 101

2/11, Option ID: 102

1/4, Option ID: 103

3/4, Option ID: 104

Topic – Mathematical Physics

Subtopic – Probability

Question ID:- 27

The value of the integral $\int_{-\infty}^{\infty} \frac{\cos \alpha x}{x^2+1} dx$, for $\alpha > 0$, is

Options:-

πe^{α}, Option ID :- 105,

$\pi e^{-\alpha}$, Option ID :- 106,

$\pi e^{-\alpha/2}$, Option ID :- 107

$\pi e^{\alpha/2}$, Option ID :- 108,

Topic – Mathematical Physics

Subtopic – Complex Analysis

Question ID:- 28

The Laplace transform $L[f](y)$ of the function $f(x) = \begin{cases} 1 & \text{for } 2n \leq x \leq 2n+1 \\ 0 & \text{for } 2n+1 \leq x \leq 2n+2 \end{cases}$, $n = 0,1,2,\cdots$ is

Options:-

$\frac{e^{-y}(e^{-y}+1)}{y(e^{-2y}+1)}$, Option ID : − 109, $\frac{e^{y}-e^{-y}}{y}$, Option ID : − 110,

$\frac{e^{y}+e^{-y}}{y}$, Option ID : − 111, $\frac{e^{y}(e^{y}-1)}{y(e^{2y}-1)}$, Option ID : − 112,

Topic – Mathematical Physics

Subtopic – Laplace Transform

Question ID:- 29

The matrix corresponding to the differential operator $\left(1+\frac{d}{dx}\right)$ in the space of polynomials of degree at most two, in the basis spanned by $f_1 = 1, f_2 = x$ and $f_3 = x^2$, is

Options:-

$\begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 2 \\ 0 & 0 & 1 \end{pmatrix}$, Option ID :- 113, $\begin{pmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & 2 & 1 \end{pmatrix}$, Option ID : − 114,

$\begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 2 \end{pmatrix}$, Option ID : − 115, $\begin{pmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & 1 & 2 \end{pmatrix}$, Option ID : − 113,

Topic – Mathematical Physics

Subtopic – Matrices

Question ID:- 30

The Lagrangian of a system of two particles is $L = \frac{1}{2}\dot{x}_1^2 + 2\dot{x}_2^2 - \frac{1}{2}(x_1^2 + x_2^2 + x_1x_2)$. The normal frequencies are best approximated by

Options:-

1.2 and 0.7, Option ID :- 117,

1.5 and 0.5, Option ID :- 118,

1.7 and 0.5, Option ID :- 119,

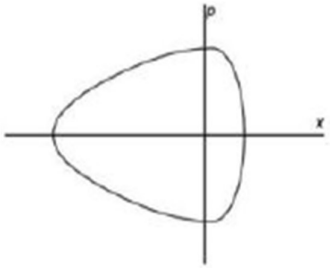
1.0 and 0.4, Option ID :- 120,

Topic – Classical Mechanics

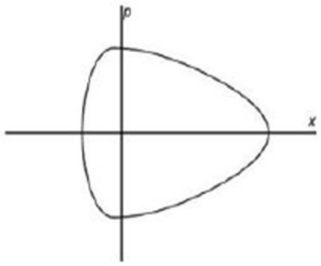
Subtopic – Small Oscillations

Question ID:- 31

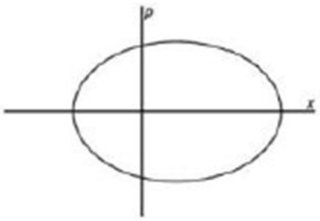
The Lagrangian of a particle in one dimension is $L = \frac{m}{2}\dot{x}^2 - ax^2 - V_0e^{-10x}$ where a and V_0 are positive constants. The best qualitative representation of a trajectory in the phase space is



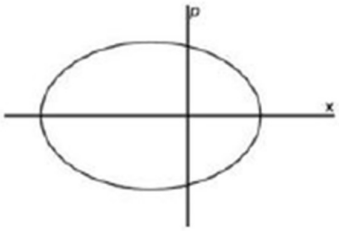
Option ID:- 121,



Option ID:- 122,



Option:- 123,



Option:- 124

Topic – Classical Mechanics

Subtopic – Phase Space

Question ID:- 32

Earth may be assumed to be an axially symmetric freely rotating rigid body. The ratio of the principal moments of inertia about the axis of symmetry and an axis perpendicular to it is 33: 32. If T_0 is the time taken by earth to make one rotation around its axis of symmetry, then the time period of precession is closest to

Options:-

33 T_0, Option ID :- 125,

$33T_0/2$, Option ID :- 126,

$32T_0$, Option ID :- 127,

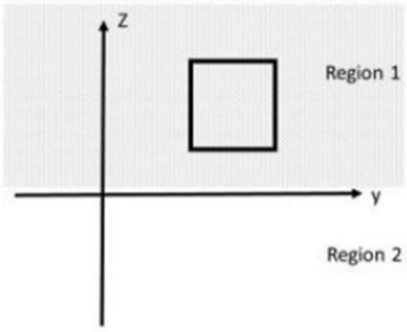
$16T_0$, Option ID :- 128,

Topic – Classical Mechanics

Subtopic – Moment of Inertia

Question ID:- 33

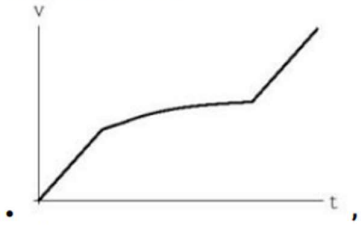
A square conducting loop in the yz-plane, falls downward under gravity along the negative z-axis. Region 1 , defined by $z > 0$ has a uniform magnetic field $\mathbf{B} = B_0\hat{\mathbf{i}}$, while region 2 (defined by $z < 0$) has no magnetic field.



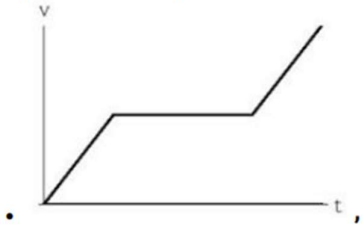
The time dependence of the speed $v(t)$ of the loop, as it starts to fall from well within the region 1 and passes into the region 2 , is best represented by

Options:-

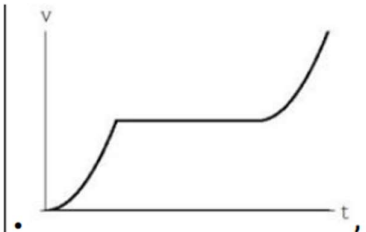
• **Option ID :- 129,**



• **Option ID :- 130,**



• **Option ID :- 131,**



• **Option ID :- 132,**

Topic – Electromagnetic Theory

Subtopic – Electrodynamics

Question ID:- 34

Two small metallic objects are embedded in a weakly conducting medium of conductivity σ and dielectric constant ϵ. A battery connected between them leads to a potential difference V_0. It is subsequently disconnected at time $t = 0$. The potential difference at a later time t is

Options:-

$V_0 e^{-\frac{t\sigma}{4\epsilon}}$, Option ID :- 133,

$V_0 e^{-\frac{t\sigma}{2\epsilon}}$, Option ID :- 134,

$V_0 e^{-\frac{3t\sigma}{4\epsilon}}$, Option ID :- 135,

$V_0 e^{-\frac{t\sigma}{\epsilon}}$, Option ID :- 136,

Topic – Electromagnetic Theory

Subtopic – Continuity Equation

Question ID:- 35

A stationary magnetic dipole $\mathbf{m} = m\hat{\mathbf{k}}$ is placed above an infinite surface $(z = 0)$ carrying a uniform surface current density $\boldsymbol{\kappa} = \kappa\hat{\mathbf{i}}$. The torque on the dipole is

Options:-

$\frac{\mu_0}{2} m\kappa\hat{\mathbf{i}}$, Option ID :- 137,

$-\frac{\mu_0}{2} m\kappa\hat{\mathbf{i}}$, Option ID :- 138,

$\frac{\mu_0}{2} m\kappa\hat{j}$, Option ID :- 139,

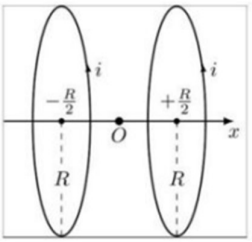
$-\frac{\mu_0}{2} m\kappa\hat{j}$, Option ID :- 140

Topic – Electromagnetic Theory

Subtopic – Magnetostatics

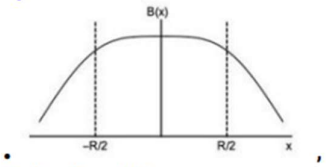
Question ID:- 36

Two parallel conducting rings, both of radius R, are separated by a distance R. The planes of the rings are perpendicular to the line joining their centres, which is taken to be the x-axis.

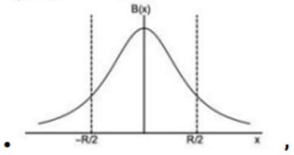


If both the rings carry the same current i along the same direction, the magnitude of the magnetic field along the x axis is best represented by

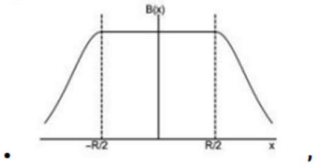
Options:-



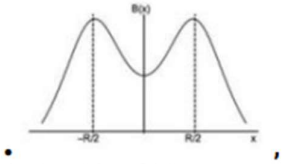
Option ID :- 141,



Option ID :- 142,



Option ID :- 143,



Option ID :- 144,

Topic – Electromagnetic Theory

Subtopic – Magnetostatics

Question ID:- 37

At time $t = 0$, a particle is in the ground state of the Hamiltonian $H(t) = \frac{p^2}{2m} + \frac{1}{2}m\omega^2x^2 + \lambda x \sin\frac{\omega t}{2}$ where λ, ω and m are positive constants. To $O(\lambda^2)$, the probability that at $t = \frac{2\pi}{\omega}$, the particle would be in the first excited state of $H(t = 0)$ is

Options:-

$\frac{9\lambda^2}{16m\hbar\omega^3}$, Option ID :- 145, $\frac{9\lambda^2}{8m\hbar\omega^3}$, Option ID : − 146,

$\frac{16\lambda^2}{9m\hbar\omega^3}$, Option ID : − 147, $\frac{8\lambda^2}{9m\hbar\omega^3}$, Option ID : − 148,

Topic – Quantum Mechanics

Subtopic – Time Dependent Perturbation Theory

Question ID:- 38

To first order in perturbation theory, the energy of the ground state of the Hamiltonian

$$H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2x^2 + \frac{\hbar\omega}{\sqrt{512}}\exp\left[-\frac{m\omega}{\hbar}x^2\right]$$

(treating the third term of the Hamiltonian as a perturbation) is

Options:-

$\frac{15}{32}\hbar\omega$, Option ID: 149, $\frac{17}{32}\hbar\omega$, Option ID: 150

$\frac{19}{32}\hbar\omega$, Option ID: 151, $\frac{21}{32}\hbar\omega$, Option ID: 149

Topic – Quantum Mechanics

Subtopic – Time Independent Perturbation Theory

Question ID:- 39

The energy/energies E of the bound state(s) of a particle of mass m in one dimension in the potential $V(x) = \begin{cases} \infty, & x \le 0 \\ -V_0, & 0 < x < a \\ 0, & x \ge a \end{cases}$ (where $V_0 > 0$) is/are determined by

Options:-

$\cot^2\left(a\sqrt{\frac{2m(E+V_0)}{\hbar^2}}\right) = \frac{E-V_0}{E}$, Option ID : − 153,

$\tan^2\left(a\sqrt{\frac{2m(E+V_0)}{\hbar^2}}\right) = -\frac{E}{E+V_0}$, Option ID : − 154,

$\cot^2\left(a\sqrt{\frac{2m(E+V_0)}{\hbar^2}}\right) = -\frac{E}{E+V_0}$, Option ID : – 155,

$\tan^2\left(a\sqrt{\frac{2m(E+V_0)}{\hbar^2}}\right) = \frac{E-V_0}{E}$, Option ID : – 156

Topic – Quantum Mechanics

Subtopic – Finite Potential Well

Question ID:- 40

The energy levels of a system, which is in equilibrium at temperature $T = 1/(k_B\beta)$, are $0, \epsilon$ and 2ϵ. If two identical bosons occupy these energy levels, the probability of the total energy being 3ϵ, is

Options:-

$\frac{e^{-3\beta\epsilon}}{1+e^{-\beta}+e^{-2\beta\epsilon}+e^{-3\beta\epsilon}+e^{-4\beta\epsilon}}$

Option ID :- 157,

$\frac{e^{-3\beta\epsilon}}{1+2e^{-\beta\epsilon}+2e^{-2\beta\epsilon}+e^{-3\beta\epsilon}+e^{-4\beta\epsilon}}$

Option ID :- 158,

$\frac{e^{-3\beta\epsilon}}{e^{-\beta\epsilon}+2e^{-2\beta\epsilon}+e^{-3\beta\epsilon}+e^{-4\beta\epsilon}}$

Option ID :- 159,

$\frac{e^{-3\beta\epsilon}}{1+e^{-\beta\epsilon}+2e^{-2\beta\epsilon}+e^{-3\beta\epsilon}+e^{-4\beta\epsilon}}$

Option ID :- 160

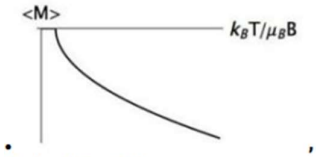
Topic – Statistical Mechanics

Subtopic – Partition Function

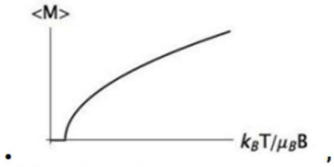
Question ID:- 41

A paramagnetic salt with magnetic moment per ion $\mu_{\pm} = \pm\mu_B$ (where μ_B is the Bohr magneton) is in thermal equilibrium at temperature T in a constant magnetic field B. The average magnetic moment $\langle M \rangle$, as a function of $\frac{k_B T}{\mu_B B}$, is best represented by

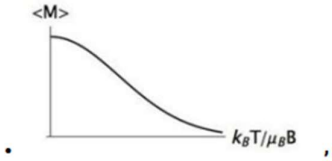
Options:-



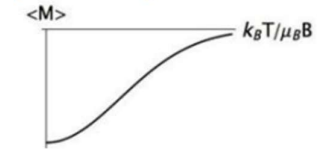
Option ID :- 161,

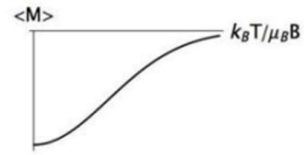


Option ID :- 162,



Option ID :- 163,





Option ID :- 164,

Topic – Condensed Matter Physics

Subtopic – Magnetism

Question ID:- 42

A system of N non-interacting particles in one-dimension, each of which is in a potential $V(x) = gx^6$ where $g > 0$ is a constant and x denotes the displacement of the particle from its equilibrium position. In thermal equilibrium, the heat capacity at constant volume is

Options:-

$\frac{7}{6}Nk_B$, Option ID : − 165, $\frac{4}{3}Nk_B$, Option ID : − 166,

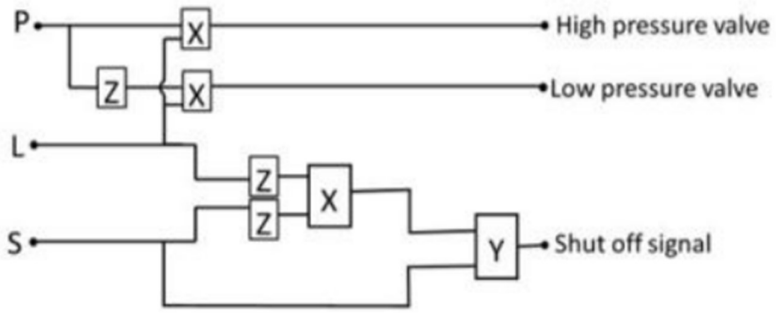
$\frac{3}{2}Nk_B$, Option ID : − 167, $\frac{2}{3}Nk_B$, Option ID : − 168,

Topic – Statistical Mechanics

Subtopic – Heat Capacity

Question ID:- 43

A liquid oxygen cylinder system is fitted with a level-sensor (L) and a pressure-sensor (P), as shown in the figure below. The outputs of L and P are set to logic high $(S = 1)$ when the measured values exceed the respective preset threshold values. The system can be shut off either by an operator by setting the input S to high, or when the level of oxygen in the tank falls below the threshold value.



The logic gates X, Y and Z, respectively, are

Options:-

OR, AND and NOT OR, Option ID:- 169,

AND, OR and NOT Option ID :- 170,

NAND, OR and NOT, Option ID :- 171,

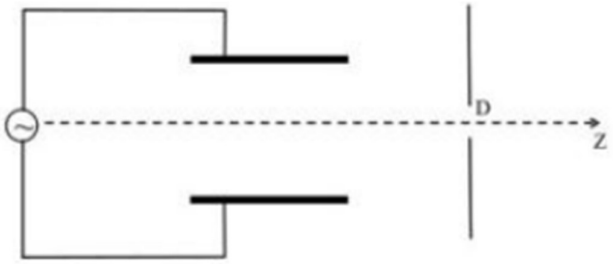
NOR, AND and NOT, Option ID :- 172,

Topic – Electronics

Subtopic – Digital Electronics

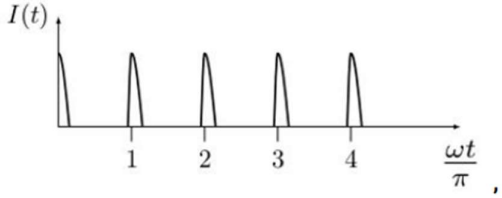
Question ID :- 44

A high frequency voltage signal $V_i = V_m \sin\ \omega t$ is applied to a parallel plate deflector as shown in the figure

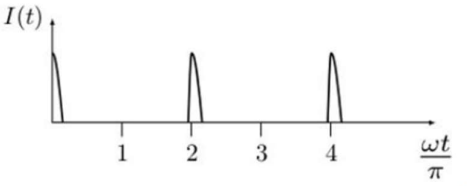


An electron beam is passing through the deflector along the central line. The best qualitative representation of the intensity $I(t)$ of the beam after it goes through the narrow circular aperture D, is

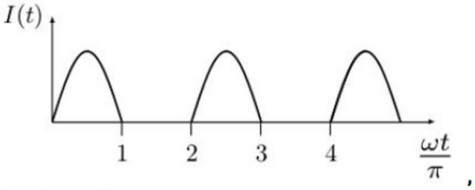
Options:-



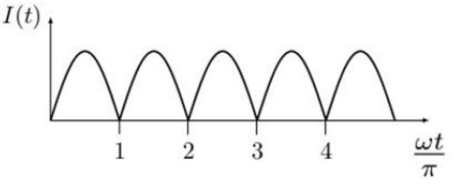
Option ID :- 173,



Option ID :- 174,



Option ID :- 175,



Option ID :- 176,

Topic – Electromagnetic Theory

Subtopic – Faraday's Law

Question ID:- 45

An amplifier with a voltage gain of 40 dB without feedback is used in an electronic circuit. A negative feedback with a fraction $1/40$ is connected to the input of this amplifier. The net gain of the amplifier in the circuit is closest to

Options

40 dB, Option ID :- 177,

37 dB, Option ID :- 178,

29 dB, Option ID :- 179,

20 dB, Option ID :- 180,

Topic – Electronics

Subtopic – OPAMP

Question ID:- 46

A receiver operating at $27^{\circ}c$ has an input resistance of 100Ω. The input thermal noise voltage for this receiver with a bandwidth of 100kHz is closest to

Options:-

0.4 nV , Option ID :- 181,

0.6 pV , Option ID :- 182,

40mV, Option ID :- 183,

$0.4\mu V$, Option ID :- 184,

Topic – Electronics

Subtopic – Instrumentation

Question ID:- 47

The Raman rotational-vibrational spectrum of nitrogen molecules is observed using an incident radiation of wavenumber $12500\ cm^{-1}$. In the first shifted band, the wavenumbers of the observed lines (in cm^{-1}) are 10150 , 10158, 10170, 10182 and 10190 . The values of vibrational frequency and rotational constant (in cm^{-1}), respectively, are

Options

2330 and 2, Option ID: 185,

2350 and 2, Option ID: 186

2350 and 3, Option ID: 187,

2330 and 3, Option ID: 187

Topic – Atomic & Molecular Physics

Subtopic – Raman Spectra

Question ID:- 48

The electronic configuration of ^{12}C is $1s^2 2s^2 2p^2$. Including LS coupling, the correct ordering of its energies is

Options:-

$E(^3P_2) < E(^3P_1) < E(^3P_0) < E(^1D_2)$, Option ID :- 189,

$E(^3P_0) < E(^3P_1) < E(^3P_2) < E(^1D_2)$, Option ID :- 190,

$E(^1D_2) < E(^3P_2) < E(^3P_1) < E(^3P_0)$, Option ID :- 191,

$E(^3P_1) < E(^3P_0) < E(^3P_2) < E(^1D_2)$, Option ID :- 192,

Topic – Atomic & Molecular Physics

Subtopic – L-S Coupling

Question ID:- 49

In the absorption spectrum of H-atom, the frequency of transition from the ground state to the first excited state is v_H. The corresponding frequency for a bound state of a positively charged muon $(\mu^+)$and an electron is v_μ. Using $m_\mu = 10^{-28}$ kg, $m_e = 10^{-30}$ kg and $m_p \gg m_e, m_\mu$, the value of $(v_\mu - v_H)/v_H$ is

Options: -

0.001, Option ID :- 193,

0.001, Option ID :- 194

-0.01, Option ID :- 195,

0.01, Option ID :- 196,

Topic – Atomic & Molecular Physics

Subtopic – Bohr Model

Question ID:- 50

The energies of a two-level system are $\pm E$. Consider an ensemble of such non-interacting systems at a temperature T. At low temperatures, the leading term in the specific heat depends on T as

Options:-

$\frac{1}{T^2}e^{-E/k_BT}$, Option ID : – 197, $\frac{1}{T^2}e^{-\frac{2E}{k_BT}}$, Option ID :- 198,

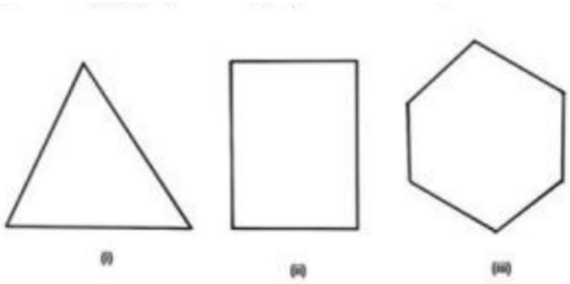
$T^2 e^{-E/k_BT}$, Option ID : – 199, $T^2 e^{-\frac{2E}{k_BT}}$, Option ID : – 200

Topic – Statistical Mechanics

Subtopic – Partition Function

Question ID:- 51

The Figures (i), (ii) and (iii) below represent an equilateral triangle, a rectangle and a regular hexagon, respectively.



Which of these can be primitive unit cells of a Bravais lattice in two dimensions?

Options:-

Only (i) and (iii) but not (ii), Option ID :- 201,

Only (i) and (ii) but not (iii), Option ID :- 202,

Only (ii) and (iii) but not (i), Option ID :- 203,

All of them, Option ID :- 204

Topic – Condensed Matter Physics

Subtopic – Crystallography

Question ID:- 52

The Hamiltonian for a spin-1/2 particle in a magnetic field $\mathbf{B} = B_0\hat{k}$ is given by $H = \lambda \mathbf{S} \cdot \mathbf{B}$, where $\mathbf{S}$ is its spin (in units of $\hbar$) and λ is a constant. If the average spin density is $\langle \mathbf{S} \rangle$ for an ensemble of such non- interacting particles, then $\frac{d}{dt}\langle S_x \rangle$

Options:-

$\frac{\lambda}{\hbar} B_0 \langle S_x \rangle$, Option ID : – 205,

$\frac{\lambda}{\hbar} B_0 \langle S_y \rangle$, Option ID : – 206,

$-\frac{\lambda}{\hbar} B_0 \langle S_x \rangle$, Option ID : – 207,

$-\frac{\lambda}{\hbar} B_0 \langle S_y \rangle$, Option ID : – 208,

Topic – Quantum Mechanics

Subtopic – Spin

Question ID:- 53

The tensor component of the nuclear force may be inferred from the fact that deuteron nucleus

$^{2}_{1}H$

Options:

has only one bound state with total spin $S = 1$, Option ID : − 208

has a non-zero electric quadrupole moment in its ground state, Option ID :- 209,

Is stable while triton $^{3}_{1}$H is unstable, Option ID :- 210,

Is the only two nucleon bound state , Option ID :- 212,

Topic – Nuclear & Particle Physics

Subtopic – Deuteron Problem

Question ID:- 54

The elastic scattering process $\pi^{-}p \rightarrow \pi^{-}p$ may be treated as a hard-sphere scattering. The mass of $\pi^{-}, m_{\pi} \simeq \frac{1}{6}m_{p}$, where $m_{p} \simeq 938\text{MeV}/c^{2}$ is the mass of the proton. The total scattering cross-section is closest to

Options: -

0.01 milli-barn, Option ID:- 213,

1 milli-barn, Option ID:- 214,

0.1 barn, Option ID:- 215,

10 barn, Option ID:- 216,

Topic – Nuclear & Particle Physics

Subtopic – Particle Physics

Question ID:- 55

Thermal neutrons may be detected most efficiently by a

Options:-

Li^{6} loaded plastic scintillator, Option ID :- 217,

Geiger-Müller counter, Option ID :- 218,

inorganic scintillatorCaF2, Option ID :- 219,

silicon detector, Option ID :- 220,

Topic – Nuclear & Particle Physics

Subtopic – Nuclear Detector