

DU PhD in Physics

Topic:- DU_J18_PHD_PHY_Topic01

1) An infinite long wire carries a time independent current $I=1$ Ampere. The wire is bent and a semi-circle detour of radius $R = 1$ cm is made with the centre at the origin. The magnitude of magnetic field at the origin is

[Question ID = 19633]

1. $\frac{25 \mu_0}{4\pi} \text{ T}$ [Option ID = 48525]
2. $2.5 \mu_0 \text{ T}$ [Option ID = 48523]
3. $25 \mu_0 \text{ T}$ [Option ID = 48524]
4. $\frac{2.5 \mu_0}{4\pi} \text{ T}$ [Option ID = 48526]

Correct Answer :-

- $25 \mu_0 \text{ T}$ [Option ID = 48524]

2) In a rotational structure of electronic bands (the transition between rotational levels of the different electronic levels) having larger rotational constant of the upper electronic level than the lower one,

[Question ID = 19617]

1. band head appears in R-branch [Option ID = 48460]
2. band head appears in P-branch [Option ID = 48459]
3. band head appears in Q-branch [Option ID = 48461]
4. no band head appears [Option ID = 48462]

Correct Answer :-

- band head appears in P-branch [Option ID = 48459]

3) In a bistable multivibrator, commutating capacitors are used to

[Question ID = 19610]

1. change the frequency of the output [Option ID = 48433]
2. provide a.c. coupling [Option ID = 48432]
3. increase the base storage output [Option ID = 48434]
4. increase the speed of response [Option ID = 48431]

Correct Answer :-

- increase the speed of response [Option ID = 48431]

4) In the Geiger Muller (GM) region, when the applied voltage is increased, which of the following happens: [Question ID = 19623]

1. The pulse amplitude increases but the counting rate remains nearly constant. [Option ID = 48483]
2. The pulse amplitude remains nearly constant and the counting rate increases. [Option ID = 48484]
3. Both the pulse amplitude and the counting rate increases. [Option ID = 48485]
4. Both the pulse amplitude and counting rate remain nearly constant. [Option ID = 48486]

Correct Answer :-

- The pulse amplitude increases but the counting rate remains nearly constant. [Option ID = 48483]

5) In the absorption spectra of harmonic vibrating diatomic oscillator, only one spectral line is observed. It is because [Question ID = 19618]

1. Separation between any two adjacent E-level is same [Option ID = 48465]
2. All other lines are very weak in intensity [Option ID = 48466]
3. Only one molecule is present in a particular E-level [Option ID = 48464]
4. Only one transition is possible from ground E level to higher E level [Option ID = 48463]

Correct Answer :-

- Separation between any two adjacent E-level is same [Option ID = 48465]

6) Magnetic field required to bend a non-relativistic charge particle of energy E in an arc of radius R is [Question ID = 19632]

1. inversely proportional to \sqrt{E} and directly proportional to R. [Option ID = 48520]
2. directly proportional to E and inversely proportional to R^2 . [Option ID = 48521]
3. directly proportional to \sqrt{E} and inversely proportional to R. [Option ID = 48519]
4. inversely proportional to \sqrt{E} and directly proportional to R^2 . [Option ID = 48522]

Correct Answer :-

- directly proportional to \sqrt{E} and inversely proportional to R. [Option ID = 48519]

7) The number of ways in which two particles can be distributed in six states, if the particles are indistinguishable and only one particle can occupy any one state, is [Question ID = 19612]

1. 31 [Option ID = 48440]
2. 36 [Option ID = 48439]
3. 21 [Option ID = 48442]
4. 25 [Option ID = 48441]

Correct Answer :-

8) Consider a 2-D harmonic oscillator with mass m and frequency ω . A perturbation $H' = bxy$ is applied to the system, where x and y are the two spatial coordinates. The first order correction to the ground state energy is

[Question ID = 19635]

1. 0 [Option ID = 48531]
2. $\pm \frac{b\hbar}{2m\omega}$ [Option ID = 48534]
3. $\frac{b\hbar}{2m\omega}$ [Option ID = 48532]
4. $-\frac{b\hbar}{2m\omega}$ [Option ID = 48533]

Correct Answer :-

- 0 [Option ID = 48531]

9) An electron of charge $-e$ is decelerated at a constant rate from an initial velocity v_0 to rest over a distance d ($v_0 \ll c$). The energy lost to radiation is given by

[Question ID = 19630]

1. $\frac{\mu_0 e^2 v_0^3}{6 \pi c d}$ [Option ID = 48512]
2. $\frac{\mu_0 e^2 v_0^3}{3 \pi c d}$ [Option ID = 48511]
3. Cannot be determined from the information supplied. [Option ID = 48514]
4. $\frac{\mu_0 e^2 v_0^3}{12 \pi c d}$ [Option ID = 48513]

Correct Answer :-

- $\frac{\mu_0 e^2 v_0^3}{12 \pi c d}$ [Option ID = 48513]

The lattice constant and saturation magnetization of BCC iron at 0 K are 2.87 \AA and 1950 kAm^{-1} , respectively. The net magnetic moment per iron atom in the crystal is

[Question ID = 19597]

1. $2.30 \times 10^{-23} \text{ A m}^2$ [Option ID = 48380]
2. $0.67 \times 10^{-21} \text{ A m}^2$ [Option ID = 48382]
3. $7.30 \times 10^{-25} \text{ A m}^2$ [Option ID = 48379]
4. $1.87 \times 10^{-22} \text{ A m}^2$ [Option ID = 48381]

Correct Answer :-

- $2.30 \times 10^{-23} \text{ A m}^2$ [Option ID = 48380]

11) Consider the density matrix of a two level system given by

$$\rho = \frac{2}{3}|1\rangle\langle 1| + \frac{1}{3}|2\rangle\langle 2|.$$

Then

[Question ID = 19615]

1. The expectation value of the operator $O_2 = \frac{\hbar}{2}(|1\rangle\langle 2| + |2\rangle\langle 1|)$ is $\frac{5\hbar}{6}$. [Option ID = 48452]
2. The expectation value of the operator $O_1 = \frac{\hbar}{2}(|1\rangle\langle 1| - |2\rangle\langle 2|)$ is $\frac{\hbar}{6}$. [Option ID = 48451]
3. The system is in a pure state. [Option ID = 48453]
4. $\langle O_1 \rangle = 0$, where $O_1 = \frac{\hbar}{2}(|1\rangle\langle 1| - |2\rangle\langle 2|)$. [Option ID = 48454]

Correct Answer :-

- The expectation value of the operator $O_1 = \frac{\hbar}{2}(|1\rangle\langle 1| - |2\rangle\langle 2|)$ is $\frac{\hbar}{6}$. [Option ID = 48451]

12) A quantum-mechanical particle of mass m and charge q is subjected to a potential of the form $V(\vec{r}) = \frac{1}{2}m\omega^2 \vec{r}^2$, where ω is a constant. An electric field $\vec{E} = E_0 \hat{x}$ is now switched on (E_0 being a constant). What is the consequent change, upto second order in E_0 , in the energy of the second excited state?

[Question ID = 19594]

1. $\frac{q^2 E_0^2}{m\hbar\omega}$ [Option ID = 48368]
2. $\frac{q^2 E_0^2 \langle x^2 \rangle}{(m\hbar\omega)^2}$ [Option ID = 48370]
3. $\frac{q^2 E_0^2}{2m\omega^2}$ [Option ID = 48367]
4. $\frac{2q^2 E_0^2}{m\omega^2}$ [Option ID = 48369]

Correct Answer :-

- $\frac{q^2 E_0^2}{2m\omega^2}$ [Option ID = 48367]

13)

For the infinite square well potential the unperturbed wave functions are

$$\psi_n^0(x) = \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi}{a} x\right)$$

If the floor of the well is raised by V_0 , the first order correction to the energy is

[Question ID = 19591]

1. $\frac{V_0}{4}$ [Option ID = 48358]
2. $\frac{V_0}{2}$ [Option ID = 48356]
3. $\frac{V_0}{3}$ [Option ID = 48357]
4. V_0 [Option ID = 48355]

Correct Answer :-

- V_0 [Option ID = 48355]

- 14) Lead (Pb) starts superconducting at 7.19 K when the applied magnetic field is zero. When a magnetic field of 0.074 Tesla is applied at 2 K, superconductivity disappears. The critical magnetic field for Lead (Pb) is

[Question ID = 19599]

1. 0.04 T [Option ID = 48388]
2. 0.08 T [Option ID = 48390]
3. 0.034 T [Option ID = 48387]
4. 0.068 T [Option ID = 48389]

Correct Answer :-

- 0.08 T [Option ID = 48390]

- 15) If \hat{A} and \hat{B} are two linear operators, then the commutator bracket $[\hat{A}, \hat{B}^{-1}]$ is equal to

[Question ID = 19586]

1. $\hat{A}^{-1}[\hat{A}, \hat{B}] \hat{B}^{-1}$ [Option ID = 48335]
2. $-\hat{A}^{-1}[\hat{A}, \hat{B}] \hat{A}^{-1}$ [Option ID = 48336]
3. $\hat{B}^{-1}[\hat{A}, \hat{B}] \hat{A}^{-1}$ [Option ID = 48337]
4. $-\hat{B}^{-1}[\hat{A}, \hat{B}] \hat{B}^{-1}$ [Option ID = 48338]

Correct Answer :-

- $-\hat{B}^{-1}[\hat{A}, \hat{B}] \hat{B}^{-1}$ [Option ID = 48338]

- 16) For a simple harmonic oscillator of mass m and angular frequency ω , let $|n\rangle$ represent the n -th energy eigenstate so that $\hat{H}|n\rangle = \hbar\omega\left(n + \frac{1}{2}\right)|n\rangle$. The physical state at time $t = 0$ is represented by $|\psi(0)\rangle = \frac{1}{\sqrt{3}}|2\rangle - \frac{1}{\sqrt{2}}|3\rangle - \frac{1}{\sqrt{6}}|1\rangle$. If one makes a measurement of the energy of the system at any subsequent time t , the probability of finding the energy to be $3\hbar\omega/2$:

[Question ID = 19589]

- depends on time t . [Option ID = 48350]
- is $\frac{1}{2}$. [Option ID = 48348]
 - is $1/6$. [Option ID = 48349]
 - is 0. [Option ID = 48347]

Correct Answer :-

- is $1/6$. [Option ID = 48349]

- 17) For temperatures 10 K and 20 K, a superconductor has the critical magnetic field as 0.15 Tesla and 0.60 Tesla, respectively. The transition temperature for this superconductor in Kelvin is

[Question ID = 19596]

- 23.3 [Option ID = 48378]
- 15.0 [Option ID = 48376]
- 22.4 [Option ID = 48377]
- 4.2 [Option ID = 48375]

Correct Answer :-

- 18) A theory has equally spaced nondegenerate energy levels starting from $E_{min} = E_0$ all the way upto $E = \infty$. The system of many such particles is at equilibrium at a temperature T . If the average energy-squared of the particles is given by

$$\langle E^2 \rangle = 5E_0^2$$

What is T ?

[Question ID = 19614]

- $T = E_0/2k_B$ [Option ID = 48449]
- $T = 2E_0/k_B$ [Option ID = 48448]
- $T = 3E_0/2k_B$ [Option ID = 48450]
- $T = E_0/k_B$ [Option ID = 48447]

Correct Answer :-

- $T = E_0/k_B$ [Option ID = 48447]

- 19) The Hamiltonian for a spin $1/2$ particle of mass m in an external field is given by

$$\hat{H} = \frac{\vec{p} \cdot \vec{p}}{2m} + g(t)\vec{\sigma} \cdot \vec{p}$$

where $g(t)$ is a time-dependent coupling constant and $\vec{\sigma}$ are the Pauli matrices. Which of the following statements is true?

[Question ID = 19590]

- The energy and all the components of the spin angular momentum of the particle are conserved. [Option ID = 48351]
- The linear momentum and all the components of the spin angular momentum of the particle are conserved. [Option ID = 48354]
- The linear momentum and the magnitude of the spin angular momentum of the particle are conserved. [Option ID = 48353]
- The linear momentum and the energy of the particle are conserved. [Option ID = 48352]

Correct Answer :-

The linear momentum and the magnitude of the spin angular momentum

of the particle are conserved.

[Option ID = 48353]

- 20) A solid contains N spin-half magnetic atoms. At sufficiently high temperatures, the atoms are randomly oriented, while at sufficiently low temperatures, they are perfectly aligned. The heat capacity is given by

$$C(T) = \begin{cases} C_0 \left(\frac{T}{T_0} - 1 \right), & T_0 \leq T \leq 3T_0 \\ 0, & \text{Otherwise} \end{cases}$$

where C_0 and T_0 are constants. Determine the maximum value of C_0 .

[Question ID = 19613]

1. $\frac{Nk_B \ln 2}{2 - \ln 3}$ [Option ID = 48445]
2. $\frac{Nk_B \ln 2}{2}$ [Option ID = 48443]
3. $\frac{2Nk_B \ln 2}{2 + \ln 3}$ [Option ID = 48446]
4. $\frac{Nk_B \ln 2}{\ln 3}$ [Option ID = 48444]

Correct Answer :-

1. $\frac{Nk_B \ln 2}{2 - \ln 3}$ [Option ID = 48445]

- 21) Green's function corresponding to the Laplacian operator ∇^2 is

$$G(\vec{r}, \vec{r}') = -\frac{1}{4\pi|\vec{r} - \vec{r}'|}$$

The value of $\phi(\vec{0})$ corresponding to the solution of the inhomogeneous differential equation

$$\nabla^2 \phi = \frac{A \exp(-\beta r)}{r}$$

(where A and β are positive numbers) is equal to,

[Question ID = 19625]

1. 0 [Option ID = 48491]
2. $\frac{A}{4\pi\beta}$ [Option ID = 48494]
3. $-\frac{A}{\beta}$ [Option ID = 48492]
4. $\frac{\pi\beta}{A}$ [Option ID = 48493]

Correct Answer :-

3. $-\frac{A}{\beta}$ [Option ID = 48492]

- 22) A star is pulsating isotropically. Its gravitational force on any body, at distances much larger than its own mean radius, is given by

$$\vec{F}(\vec{r}) = \left(\frac{-k}{r^3} + \frac{a}{r^4} \right) \vec{r}$$

where k and a are positive constants. Which of the following is true about the motion of the body?

[Question ID = 19604]

1. Any bounded motion is described by a precessing ellipse. [Option ID = 48407]
2. No bounded motion exists at all. [Option ID = 48410]
3. Any bounded motion is described by a pulsating ellipse. [Option ID = 48408]
Any bounded motion is still in an elliptical path, but the parameters of the ellipse are shifted from those in the Newtonian case.
4. [Option ID = 48409]

Correct Answer :-

- Any bounded motion is described by a precessing ellipse. [Option ID = 48407]

23) The Hamiltonian for a particle in one dimension is given by

$$H(x, p) = \frac{p^2}{2m} + \lambda px + \frac{\lambda}{2} x^2$$

where m, λ are constants. The corresponding Lagrangian is

[Question ID = 19603]

1. $L = \frac{m}{2} (\dot{x})^2 - \lambda mx\dot{x} - \frac{\lambda}{2} x^2$ [Option ID = 48405]
2. $L = \frac{m}{2} (\dot{x} - \lambda x)^2 - \lambda mx\dot{x} - \frac{\lambda}{2} x^2$ [Option ID = 48406]
3. $L = \frac{m}{2} (\dot{x} - \lambda x)^2 - \frac{\lambda}{2} x^2$ [Option ID = 48404]
4. $L = \frac{m}{2} (\dot{x})^2 - \frac{\lambda}{2} x^2$ [Option ID = 48403]

Correct Answer :-

- $L = \frac{m}{2} (\dot{x} - \lambda x)^2 - \frac{\lambda}{2} x^2$ [Option ID = 48404]

24) Consider the 2π -periodic function $f(x)$ defined as

$$f(x) = \begin{cases} x(\pi - x), & x \in [0, \pi] \\ x(x - \pi), & x \in [-\pi, 0] \end{cases}$$

Which of the following is true?

[Question ID = 19627]

1. $f(x) = \frac{4}{\pi} \sum_{k=0}^{\infty} \frac{\sin[(2k+1)x]}{(2k+1)^2}$ [Option ID = 48502]
2. $f(x) = \frac{8}{\pi} \sum_{k=0}^{\infty} \frac{\sin(kx)}{k^3}$ [Option ID = 48500]
3. $f(x) = \frac{4}{\pi} \sum_{k=0}^{\infty} \frac{\sin(kx)}{k^2} + \frac{4}{\pi} \sum_{k=0}^{\infty} \frac{\cos(kx)}{k^2}$ [Option ID = 48499]
4. $f(x) = \frac{8}{\pi} \sum_{k=0}^{\infty} \frac{\sin[(2k+1)x]}{(2k+1)^3}$ [Option ID = 48501]

Correct Answer :-

- $f(x) = \frac{8}{\pi} \sum_{k=0}^{\infty} \frac{\sin[(2k+1)x]}{(2k+1)^3}$ [Option ID = 48501]

25) In 3-dimensional space, a particle of mass m moves in a potential $A \cos^2 \beta r$ where r is the distance of the particle from the origin, A and β are real constants. Which of the following statements are correct?

[Question ID = 19600]

1. The motion is periodic in r with an oscillation distance π/β . [Option ID = 48394]
2. The motion is periodic in r with an oscillation distance $2\pi/\beta$. [Option ID = 48392]
3. The trajectory of the particle is always confined to some plane passing through the origin. [Option ID = 48391]
4. The radial momentum p_r is conserved because of the periodic nature of the potential. [Option ID = 48393]

Correct Answer :-

- The trajectory of the particle is always confined to some plane passing through the origin. [Option ID = 48391]

- 26) The $^{90}\text{Sr} \xrightarrow{\beta^-} ^{90}\text{Y} \xrightarrow{\beta^-} ^{90}\text{Zr}$ chain decays with a half-life of 28 years and 64 hours, respectively. If 1g of pure ^{90}Sr is allowed to decay, then the ratio $(N_{\text{Sr}}/N_{\text{Y}})$ after 1 hour is

[Question ID = 19621]

1. 3.56×10^4 [Option ID = 48477]
2. 3.56×10^5 [Option ID = 48475]
3. 4.56×10^4 [Option ID = 48478]
4. 4.56×10^5 [Option ID = 48476]

Correct Answer :-

- 3.56×10^5 [Option ID = 48475]

- 27) For the electronic configuration $2p3d$, the complete spectroscopic terms in Russell-Saunders coupling scheme are

[Question ID = 19587]

1. $^1\text{P}, ^1\text{D}, ^1\text{F}, ^1\text{G}, ^1\text{H}, ^3\text{P}, ^3\text{D}, ^3\text{F}, ^3\text{G}, ^3\text{H}$ [Option ID = 48339]
2. $^2\text{P}, ^2\text{D}, ^2\text{F}, ^4\text{P}, ^4\text{D}, ^4\text{F}$ [Option ID = 48342]
3. $^2\text{S}, ^2\text{P}, ^2\text{D}, ^2\text{F}, ^4\text{S}, ^4\text{P}, ^4\text{D}, ^4\text{F}$ [Option ID = 48340]
4. $^1\text{P}, ^1\text{D}, ^1\text{F}, ^3\text{P}, ^3\text{D}, ^3\text{F}$ [Option ID = 48341]

Correct Answer :-

- $^1\text{P}, ^1\text{D}, ^1\text{F}, ^3\text{P}, ^3\text{D}, ^3\text{F}$ [Option ID = 48341]

- 28) The Hamiltonian of a two-level system is given by $H = \frac{1}{2} \hbar \omega \sigma_x$. At time $t = 0$ the system is in the eigenstate of σ_x having the largest eigenvalue. The expectation values $\langle \sigma_x \rangle(t)$, $\langle \sigma_y \rangle(t)$ and $\langle \sigma_z \rangle(t)$ (where σ_i are Pauli matrices) are respectively

[Question ID = 19592]

1. $\sin\left(\frac{\omega t}{2}\right), 0$, and $\cos\left(\frac{\omega t}{2}\right)$ [Option ID = 48361]
2. $\cos\left(\frac{\omega t}{2}\right), \sin\left(\frac{\omega t}{2}\right)$ and 0 [Option ID = 48359]
3. $0, \cos\left(\frac{\omega t}{2}\right)$ and $\sin\left(\frac{\omega t}{2}\right)$ [Option ID = 48360]

4. $-\cos\left(\frac{\omega t}{2}\right), 0, \text{ and } \sin\left(\frac{\omega t}{2}\right)$ [Option ID = 48362]

Correct Answer :-

- $\cos\left(\frac{\omega t}{2}\right), \sin\left(\frac{\omega t}{2}\right) \text{ and } 0$ [Option ID = 48359]

29) The Lagrangian for a system is given by $L = \dot{q}_1 \dot{q}_2 - \omega^2 q_1 q_2$ where ω is a constant and $\dot{q}_i = \frac{dq_i}{dt}$. L is invariant under the following transformations $q_1 = e^\alpha q_1$ and $q_2 = e^{-\alpha} q_2$, α is a constant. The conserved quantity corresponding to this symmetry transformation is

[Question ID = 19601]

1. $q_1 \dot{q}_1 + q_2 \dot{q}_2$ [Option ID = 48398]
2. $q_1 \dot{q}_2 - q_2 \dot{q}_1$ [Option ID = 48395]
3. $q_1 \dot{q}_2 + q_2 \dot{q}_1$ [Option ID = 48396]
4. $q_1 \dot{q}_1 - q_2 \dot{q}_2$ [Option ID = 48397]

Correct Answer :-

- $q_1 \dot{q}_2 - q_2 \dot{q}_1$ [Option ID = 48395]

30) An integral is defined to be,

$$I = \int_0^\infty \frac{\sin x}{x} dx.$$

Then I is equal to:

[Question ID = 19628]

1. $-\frac{\pi}{\cos \sqrt{2}}$ [Option ID = 48506]
2. $\pi/2$ [Option ID = 48503]
3. $2/\pi$ [Option ID = 48505]
4. $-\frac{\cos \sqrt{2}}{\pi}$ [Option ID = 48504]

Correct Answer :-

- $\pi/2$ [Option ID = 48503]

31) In the given astable multivibrator, the frequency of the square wave generated is

[Question ID = 19607]

1. 32.4 kHz [Option ID = 48421]
2. 3.5 kHz [Option ID = 48419]
3. 324 Hz [Option ID = 48422]
4. 3.5 Hz [Option ID = 48420]

Correct Answer :-

32)

A point mass m is attached, through a massless incompressible rod of length ℓ , to a fixed point. The mass is allowed to have any motion consistent with the above. If θ be the instantaneous angle of the rod with the vertical, which of the following is necessarily true? (Here $\kappa \geq 0$ is an arbitrary constant)

[Question ID = 19605]

1. $\ddot{\theta} + \frac{g}{\ell} \sin \theta = 0$ [Option ID = 48412]
2. $\ddot{\theta} + \frac{\kappa \sin \theta}{\cos^3 \theta} + \frac{g}{\ell} \sin \theta = 0$ [Option ID = 48413]
3. $\ddot{\theta} + \frac{g}{\ell} \theta = 0$ [Option ID = 48411]
4. $\ddot{\theta} - \frac{\kappa \cos \theta}{\sin^3 \theta} + \frac{g}{\ell} \sin \theta = 0$ [Option ID = 48414]

Correct Answer :-

• $\ddot{\theta} - \frac{\kappa \cos \theta}{\sin^3 \theta} + \frac{g}{\ell} \sin \theta = 0$ [Option ID = 48414]

33) Neutrons are captured by ^{10}B to form ^{11}B , which breaks into an alpha particles and the ^7Li nucleus. Then, the kinetic energy of the ^7Li and the Q value of the reaction are (Given $M(^{10}\text{B}) = 10.01611$ amu; $M(^1_0\text{n}) = 1.008987$ amu; $M(^7\text{Li}) = 7.01822$ amu; $M(^4\text{He}) = 4.003879$ amu)

[Question ID = 19620]

1. 1.01 MeV and 2.59 MeV [Option ID = 48473]
2. 1.78 MeV and 2.79 MeV [Option ID = 48472]
3. 1.01 MeV and 2.79 MeV [Option ID = 48471]
4. 1.78 MeV and 2.59 MeV [Option ID = 48474]

Correct Answer :-

• 1.01 MeV and 2.79 MeV [Option ID = 48471]

34) An ultrafast laser produces a sequence of pulses with a repetition time of T . The pulse is a wavepacket of energy E and a central wavelength of λ . The laser beam hits a mirror at an angle θ to the normal and is reflected. The average force on the mirror is

[Question ID = 19629]

1. None of these [Option ID = 48510]
2. $\frac{2 E \cos \theta}{c T}$ [Option ID = 48509]
3. $\frac{E \cos \theta}{c T}$ [Option ID = 48507]
4. $\frac{E \cos 2 \theta}{c T}$ [Option ID = 48508]

Correct Answer :-

• $\frac{2 E \cos \theta}{c T}$ [Option ID = 48509]

35) The canonical partition function for a system of N non interacting particles is given by $\frac{1}{N!} (\alpha k T)^{3N}$, where α and k are constants. The internal energy of the system is (large N)

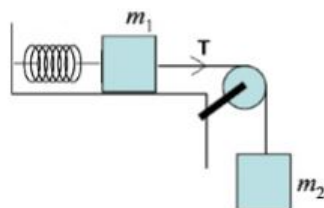
[Question ID = 19616]

1. $3NkT$ [Option ID = 48457]
2. $\frac{3}{2} NkT$ [Option ID = 48455]
3. $2NkT$ [Option ID = 48456]
4. $6NkT$ [Option ID = 48458]

Correct Answer :-

- $3NkT$ [Option ID = 48457]

- 36) The acceleration of the system given in the figure , where k is the spring constant and x is the displacement relative to the relaxed length of the spring, is



[Question ID = 19626]

1. $\frac{-kx + m_2g}{m_1 + m_2}$ [Option ID = 48497]
2. $\frac{kx - m_2g}{m_1 + m_2}$ [Option ID = 48496]
3. $\frac{-kx + m_2g}{m_1 + m_2}$ [Option ID = 48495]
4. $\frac{kx - m_1g}{m_1 + m_2}$ [Option ID = 48498]

Correct Answer :-

- $\frac{-kx + m_2g}{m_1 + m_2}$ [Option ID = 48495]

- 37) A system, in three dimensions, is described by the Lagrangian

$$L = \frac{m}{2}(\dot{x}^2 + \dot{y}^2 + \dot{z}^2) + \dot{x} \sin(t) - \frac{k}{x^2 + y^2} + x \cos(t)$$

where k is constant. Of energy (E), linear momentum (\vec{p}) and angular momentum (\vec{J}), which are conserved?

[Question ID = 19602]

1. p_z alone [Option ID = 48399]
2. E, p_z and J_z alone. [Option ID = 48402]
3. E, \vec{p}, \vec{J} [Option ID = 48401]
4. \vec{p} alone [Option ID = 48400]

Correct Answer :-

- p_z alone [Option ID = 48399]

- 38) For a simple harmonic oscillator of mass m and angular frequency ω , if $|n\rangle$ represents the n -th energy eigenstate, then the expectation value $\langle n | \hat{p}^2 | n \rangle$ is equal to:

[Question ID = 19588]

1. $m\hbar n\omega$ [Option ID = 48345]

2. $m\hbar\omega (n + 1/2)$ [Option ID = 48343]
3. $m\hbar\omega (2n + 1)$ [Option ID = 48344]
4. 0 [Option ID = 48346]

Correct Answer :-

- $m\hbar\omega (n + 1/2)$ [Option ID = 48343]

39) A feedback amplifier has an open loop gain of -100. If 4% of the output is fed back in a degenerative loop, the closed loop gain of the amplifier would be:

[Question ID = 19609]

1. +25 [Option ID = 48430]
2. +33 [Option ID = 48429]
3. -30 [Option ID = 48428]
4. -20 [Option ID = 48427]

Correct Answer :-

- -20 [Option ID = 48427]

40) In the first order X-ray (wavelength of 0.3 nm) diffraction measurement of a crystal having a body-centered cubic structure of lattice constant 0.4 nm, the diffracted beam for the (111) plane will emerge at an angle

[Question ID = 19598]

1. 20.25° [Option ID = 48384]
2. 40.5° [Option ID = 48385]
3. 81.0° [Option ID = 48386]
4. 10.12° [Option ID = 48383]

Correct Answer :-

- 40.5° [Option ID = 48385]

41) A particle of mass m moves in a screened coulomb potential given as $\vec{r} = -k \frac{e^{-ar}}{r}$, where k and a are positive constants. The condition for the existence of circular orbits for this motion would be given by

[Question ID = 19606]

1. $\dot{\theta} = \sqrt{\frac{k}{m} (1 + ar_0)} r_0^{-1/2} e^{-ar_0/2}$ [Option ID = 48417]
2. $\dot{\theta} = \sqrt{\frac{k}{m} (1 + ar_0)} r_0^{-3/2} e^{-ar_0/2}$ [Option ID = 48415]
3. $\dot{\theta} = \sqrt{\frac{k}{m} (1 - ar_0)} r_0^{-3/2} e^{-ar_0/2}$ [Option ID = 48416]
4. $\dot{\theta} = \sqrt{\frac{k}{m} (1 - ar_0)} r_0^{-1/2} e^{-ar_0/2}$ [Option ID = 48418]

Correct Answer :-

- $\dot{\theta} = \sqrt{\frac{k}{m} (1 + ar_0)} r_0^{-3/2} e^{-ar_0/2}$ [Option ID = 48415]

- 42) In a field effect transistor (FET), when the drain current changes from 1 mA to 1.9 mA with a change in gate-to-source voltage of 0.3 V, the transconductance is

[Question ID = 19608]

1. 3.0 A/V [Option ID = 48425]
2. 3.0 mA/V [Option ID = 48423]
3. 9.6 A/V [Option ID = 48426]
4. 9.6 mA/V [Option ID = 48424]

Correct Answer :-

- 3.0 mA/V [Option ID = 48423]

- 43) The solution to the non-linear differential equation,

$$\frac{df}{dx} + \alpha f^2 = 0$$
 with boundary condition $f(0) = 1$ and α a constant is given by,

[Question ID = 19624]

1. $\cos \alpha x$ [Option ID = 48487]
2. $\frac{\sin \alpha x}{\alpha x}$ [Option ID = 48488]
3. $(\alpha x + 1)^{-1}$ [Option ID = 48489]
4. $(\alpha x + 1)^{-2}$ [Option ID = 48490]

Correct Answer :-

- $(\alpha x + 1)^{-1}$ [Option ID = 48489]

- 44) The Hamiltonian for a particle of mass m in one dimension is given by

$$H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2 + \lambda|x|$$

where ω and λ are real positive constants. For a small value of λ , the ground state energy to the leading order in λ is

[Question ID = 19593]

1. $E_0 = \frac{1}{2}\hbar\omega + 2\lambda\sqrt{\frac{\hbar}{m\pi\omega}}$ [Option ID = 48366]
2. $E_0 = \frac{1}{2}\hbar\omega + \frac{3\lambda}{2}\sqrt{\frac{\hbar}{m\pi\omega}}$ [Option ID = 48364]
3. $E_0 = \frac{1}{2}\hbar\omega + \lambda\sqrt{\frac{\hbar}{m\pi\omega}}$ [Option ID = 48365]
4. $E_0 = \frac{1}{2}\hbar\omega + \frac{\lambda}{2}\sqrt{\frac{\hbar}{m\pi\omega}}$ [Option ID = 48363]

Correct Answer :-

- $E_0 = \frac{1}{2}\hbar\omega + \lambda\sqrt{\frac{\hbar}{m\pi\omega}}$ [Option ID = 48365]

45)

Three 32×32 matrices A_i are known to obey the commutation rule

$$[A_i, A_j] = i\epsilon_{ijk}A_k$$

The matrix A_1 has the following eigen values:

± 2 (twice each), ± 1 (7 times each) and 0 (14 times).

If $A^2 = A_1^2 + A_2^2 + A_3^2$, How often does A^2 have the eigenvalue 0?

[Question ID = 19595]

1. 14 times [Option ID = 48372]
2. The information is incomplete [Option ID = 48374]
3. 7 times [Option ID = 48371]
4. Never [Option ID = 48373]

Correct Answer :-

- 7 times [Option ID = 48371]

46) For a Geiger Muller (GM) Counter experiment, which of the following statement is true?

[Question ID = 19622]

1. GM counter cannot detect gamma-rays [Option ID = 48482]
2. GM counter can measure the energy of the both the beta and gamma-rays [Option ID = 48481]
3. GM Counter cannot discriminate between beta rays and gamma rays [Option ID = 48479]
4. Efficiency of the GM counter for gamma rays is more than that for beta rays. [Option ID = 48480]

Correct Answer :-

- GM Counter cannot discriminate between beta rays and gamma rays [Option ID = 48479]

47) For the molecules of an ideal gas the ratio of most probable speed to average speed to root mean square velocity is given by

[Question ID = 19611]

1. $\sqrt{2} : \sqrt{\pi/8} : \sqrt{3}$ [Option ID = 48438]
2. $\sqrt{3} : \sqrt{\pi/8} : \sqrt{2}$ [Option ID = 48437]
3. $\sqrt{3} : \sqrt{8/\pi} : \sqrt{2}$ [Option ID = 48436]
4. $\sqrt{2} : \sqrt{8/\pi} : \sqrt{3}$ [Option ID = 48435]

Correct Answer :-

- $\sqrt{2} : \sqrt{8/\pi} : \sqrt{3}$ [Option ID = 48435]

48) Consider an atom in a flame emitting in optical wavelengths. What would the typical Doppler broadening of a line be? [Question ID = 19619]

1. 10^{12} Hz [Option ID = 48467]
2. 10^3 Hz [Option ID = 48470]
3. 10^6 Hz [Option ID = 48469]
4. 10^9 Hz [Option ID = 48468]

Correct Answer :-

- 10^9 Hz [Option ID = 48468]

49) Which of the following equation is not gauge invariant? [Question ID = 19631]

1. $\nabla^2 \vec{B} - \frac{1}{c^2} \frac{\partial^2 \vec{B}}{\partial t^2} = 0$ [Option ID = 48517]

2. $\vec{\nabla} \cdot \vec{E} = 0$ [Option ID = 48518]
3. $\nabla^2 \vec{E} - \frac{1}{c^2} \frac{\partial^2 \vec{E}}{\partial t^2} = 0$ [Option ID = 48516]
4. $\vec{\nabla} \cdot \vec{A} + \frac{1}{c} \frac{\partial \phi}{\partial t} = 0$ [Option ID = 48515]

Correct Answer :-

- $\vec{\nabla} \cdot \vec{A} + \frac{1}{c} \frac{\partial \phi}{\partial t} = 0$ [Option ID = 48515]

50) A small mass m with a charge q is attached to a spring constant k and allowed to oscillate with amplitude A . Assuming that the amplitude of the oscillations and the speed of the mass is small, the time averaged power radiated by the system is

[Question ID = 19634]

1. $\frac{\mu_0 q^2 A^2 k^2}{6 \pi c m}$ [Option ID = 48529]
2. $\frac{1}{\sqrt{\epsilon_0 \mu_0^3}} \frac{q^2 A^2 k^2}{m^2}$ [Option ID = 48527]
3. $\frac{\mu_0 q^2 A^2 k^2}{12 \pi c m^2}$ [Option ID = 48530]
4. $\sqrt{\epsilon_0 \mu_0^3} \frac{q A^2 k^2}{12 \pi m^2}$ [Option ID = 48528]

Correct Answer :-

- $\frac{\mu_0 q^2 A^2 k^2}{12 \pi c m^2}$ [Option ID = 48530]