GATE 2020

PHYSICS (PH)

This question paper consists of **2 sections**, General Aptitude **(GA)** section for **15 marks** and the subject specific section **(PHYSICS)** for **85 marks**. Both these sections are compulsory.

There will be a total of 65 questions carrying 100 marks.

The GA section consists of 10 questions. Question numbers 1 to 5 are of 1 mark each, while question numbers 6 to 10 are of 2 marks each.

The subject specific **PH** section consists of **55** questions, out of which question numbers 1 to 25 are of 1 mark each, while question numbers 26 to 55 are of 2 marks each.

Use the data given in the question while answering that question. If such data are not given, and the paper has useful data, then the same can be viewed by clicking on the Useful Data button that appears at the top, right-hand side of the screen.

The question paper consists of Multiple Choice Questions (MCQ) and Numerical Answer Type (NAT).

(a) Multiple choice type questions have four choices (a), (b), (c) and (d) out of which only ONE is the correct answer.

(b) For Numerical answer type questions, a numerical answer should be entered.

All those questions that are not attempted will carry zero marks. However, wrong answers for multiple choice type questions (MCQ) will carry **NEGATIVE** marks. For multiple choice type questions, a wrong answering will lead to deduction of **1/3** marks for a 1-mark question and **2/3** marks for a 2-mark question. There is no negative marking for NAT questions.

Only Virtual Scientific Calculator is allowed. Charts, graph sheets, tables, cellular phone or other electronic gadgets are **NOT** allowed in the examination hall.

Section - GA (General Aptitude)

Q1 – Q5 carry one mark each.

Q1. He is known for his unscrupulous ways. He always sheds ___________ tears to deceive people.

(a) fox's (b) crocodile's (c) crocodile (d) fox

Q2. Jofra Archer, the England fast bowler, is __________ than accurate.

(a) more fast (b) faster (c) less fast (d) more faster

Q3. Select the word that fits the analogy:

Build : Building :: Grow :

(a) Grown (b) Grew (c) Growth (d) Growed

Q4. I do not think you know the case well enough to have opinions. Having said that, I agree with your other point.

What does the phrase "having said that" mean in the given text?

(a) as opposed to what I have said (b) despite what I have said

(c) in addition to what I have said (d) contrary to what I have said

Q5. Define $\left[x\right]$ as the greatest integer less than or equal to x, for each $x\in\left(-\infty,\infty\right)$. If $y=\left[x\right]$, then area under y for $x\in\left[1,4\right]$ is

(a) 1 (b) 3 (c) 4 (d) 6

Q6 – Q10 carry two marks each.

Q6. Crowd funding deals with mobilisation of funds for a project from a large number of people, who would be willing to invest smaller amounts through web-based platforms in the project.

Based on the above paragraph, which of the following is correct about crowd funding?

(a) Funds raised through unwilling contributions on web-based platforms

(b) Funds raised through large contributions on web-based platforms

(c) Funds raised through coerced contributions on web-based platforms

(d) Funds raised through voluntary contributions on web-based platforms

Q7. P,Q,R and S are to be uniquely coded using ~ and . If P is coded as ~~ and Q as ~ , then R and S, respectively, can be coded as

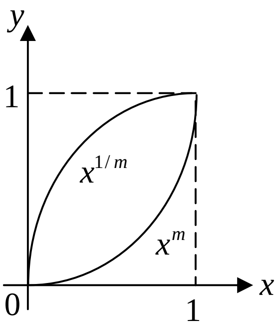
(a) ~ and ~ (b) and ~~ (c) ~ and (d) ~ and

Q8. The sum of the first n terms in the sequence $8, 88, 888, 8888, \ldots$ is

(a) $\frac{81}{80}\left(10^n - 1\right) + \frac{9}{8}n$ (b) $\frac{81}{80}\left(10^n - 1\right) - \frac{9}{8}n$

(c) $\frac{80}{81}\left(10^n - 1\right) + \frac{8}{9}n$ (d) $\frac{80}{81}\left(10^n - 1\right) - \frac{8}{9}n$

Q9. Select the graph that schematically represents BOTH $y = x^m$ and $y = x^{1/m}$ properly in the interval $0 \le x \le 1$, for integer values of m, where $m > 1$

(a)


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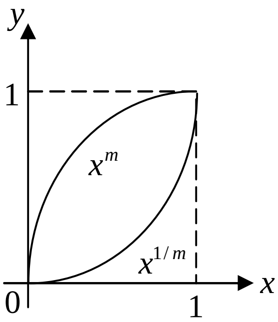

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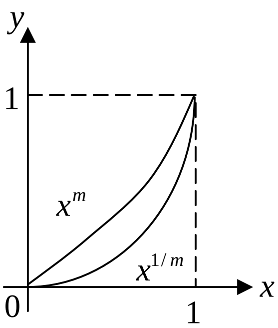
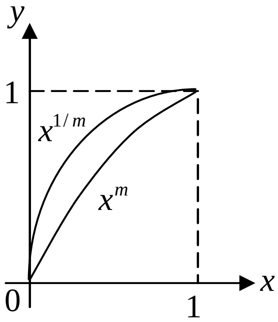
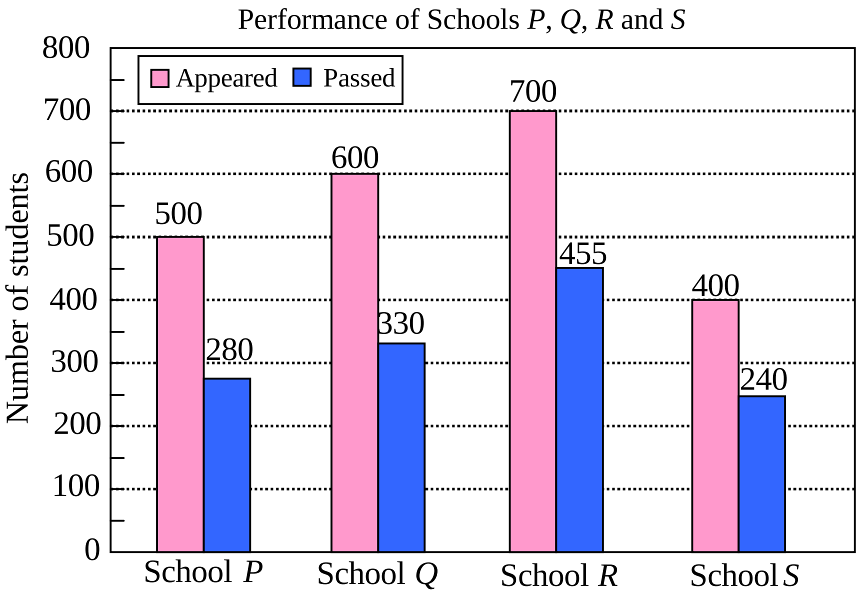


(d)


Q10. The bar graph shows the data of the students who appeared and passed in an examination for four schools P, Q, R and S. The average of success rates (in percentage) of these four school is__________.



(a) 58.5% (b) 58.8% (c) 59.0% (d) 59.3%

Q1 – Q25 carry one marks each.

Q1. Which one of the following is a solution of $\frac{d^2u(x)}{dx^2} = k^2u(x)$, for k real?

(a) e^{-kx} (b) $\sin kx$ (c) $\cos kx$ (d) $\sinh x$

Q2. A real, invertible 3×3 matrix M has eigenvalues $\text{ª}_i, (i = 1, 2, 3)$ and the corresponding eigenvectors are $|e_i\rangle, (i = 1, 2, 3)$ respectively. Which one of the following is correct?

(a) $M|e_i\rangle = \frac{1}{\text{ª}_i}|e_i\rangle$, for $i = 1, 2, 3$ (b) $M^{-1}|e_i\rangle = \frac{1}{\text{ª}_i}|e_i\rangle$, for $i = 1, 2, 3$

(c) $M^{-1}|e_i\rangle = \text{ª}_i|e_i\rangle$, for $i = 1, 2, 3$ (d) The eigenvalues of M and M^{-1} are not related

Q3. A quantum particle is subjected to the potential

$$V(x) = \begin{cases} \infty, & x \le -\frac{a}{2} \\ 0, & -\frac{a}{2} < x < \frac{a}{2} \\ \infty, & x \ge \frac{a}{2} \end{cases}$$

The ground state wave function of the particle is proportional to

(a) $\sin\left(\frac{\text{®}x}{2a}\right)$ (b) $\sin\left(\frac{\text{®}x}{a}\right)$ (c) $\cos\left(\frac{\text{®}x}{2a}\right)$ (d) $\cos\left(\frac{\text{®}x}{a}\right)$

Q4. Let $\hat{a}$ and $\hat{a}^\dagger$, respectively denote the lowering and raising operators of a one-dimensional simple harmonic oscillator. Let $|n\rangle$ be the energy eigenstate of the simple harmonic oscillator. Given that $|n\rangle$ is also an eigen state of $\hat{a}^\dagger\hat{a}^\dagger\hat{a}\hat{a}$, the corresponding eigenvalue is

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

Q5. Which one of the following is a universal logic gate?

(a) AND (b) NOT (c) OR (d) NAND

Q6. Which one of the following is the correct binary equivalent of the hexadecimal $F6C$?

(a) 0110 1111 1100 (b) 1111 0110 1100

(c) 1100 0110 1111 (d) 0110 1100 0111

Q7. The total angular momentum j of the ground state of the $^{17}_{8}O$ nucleus is

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

Q8. A particle X is produced in the process $®^{+} + p \rightarrow K^{+} + X$ via the strong interaction. If the quark content of the K^{+} is $u\bar{s}$, the quark content of X is

(a) $c\bar{s}$ (b) uud (c) uus (d) $u\bar{d}$

Q9. A medium $(£_r > 1, «_r = 1, ± > 0)$ is semi-transparent to an electromagnetic wave when

(a) Conduction current >> Displacement current

(b) Conduction current << Displacement current

(c) Conduction current = Displacement current

(d) Both Conduction current and Displacement current are zero

Q10. A particle is moving in a central force field given by $\vec{F} = -\frac{k}{r^3}\hat{r}$, where $\hat{r}$ is the unit vector pointing away from the center of the field. The potential energy of the particle is given by

(a) $\frac{k}{r^2}$ (b) $\frac{k}{2r^2}$ (c) $-\frac{k}{r^2}$ (d) $-\frac{k}{2r^2}$

Q11. Choose the correct statement related to the Fermi energy (E_F) and the chemical potential $(«)$ of a metal

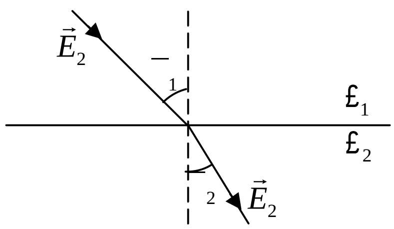
(a) $« = E_F$ only at $0K$ (b) $« = E_F$ at finite temperature

(c) $« < E_F$ at $0K$ (d) $« > E_F$ at finite temperature

Q12. Consider a diatomic molecule formed by identical atoms. If E_V and E_C represent the energy of the vibrational nuclear motion and electronic motion respectively, then in terms of the electronic mass m and nuclear mass M, $\frac{E_V}{E_C}$ is proportional to

(a) $\left(\frac{m}{M}\right)^{1/2}$ (b) $\frac{m}{M}$ (c) $\left(\frac{m}{M}\right)^{3/2}$ (d) $\left(\frac{m}{M}\right)^{2}$

Q13. Which one of the following relations determines the manner in which the electric field lines are refracted across the interface between two dielectric media having dielectric constants $£_1$ and $£_2$ (see figure)?



(a) $£_1 \sin ¯_1 = £_2 \sin ¯_2$ (b) $£_1 \cos ¯_1 = £_2 \cos ¯_2$

(c) $£_1 \tan ¯_1 = £_2 \tan ¯_2$ (d) $£_1 \cot ¯_1 = £_2 \cot ¯_2$

Q14. If $\vec{E}$ and $\vec{B}$ are the electric and magnetic fields respectively, then $\vec{E}\cdot\vec{B}$ is

(a) Odd under parity and even under time reversal

(b) Even under parity and odd under time reversal

(c) Odd under parity and odd under time reversal

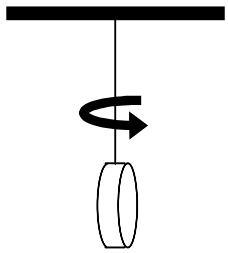
(d) Even under parity and even under time reversal

Q15. A small disc is suspended by a fiber such that it is free to rotate about the fiber axis (see figure). For small angular deflections, the Hamiltonian for the disc is given by

$$H = \frac{p_\theta^2}{2I} + \frac{1}{2}\kappa\theta^2$$

where I is the moment of inertia and κ is the restoring torque per unit deflection. The disc is subjected to angular deflections (θ) due to thermal collisions from the surrounding gas at temperature T and p_θ is the momentum conjugate to θ. The average and the root-mean-square angular deflection, θ_{avg} and $\theta_{\rm rms}$, respectively are

(a) $\theta_{avg} = 0$ and $\theta_{rms} = \left(\frac{k_B T}{\kappa}\right)^{3/2}$

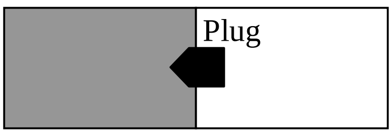


(b) $\theta_{avg} = 0$ and $\theta_{rms} = \left(\frac{k_B T}{\kappa}\right)^{1/2}$

(c) $\theta_{avg} \neq 0$ and $\theta_{rms} = \left(\frac{k_B T}{\kappa}\right)^{1/2}$

(d) $\theta_{avg} \neq 0$ and $\theta_{rms} = \left(\frac{k_B T}{\kappa}\right)^{3/2}$

Q16. As shown in the figure, an ideal gas is confined to chamber A of an insulated container, with vacuum in chamber B. When the plug in the wall separating the chambers A and B is removed, the gas fills both the chambers. Which one of the following statements is true?



(a) The temperature of the gas remains unchanged

(b) Internal energy of the gas decreases

(c) Temperature of the gas decreases as it expands to fill the space in chamber B

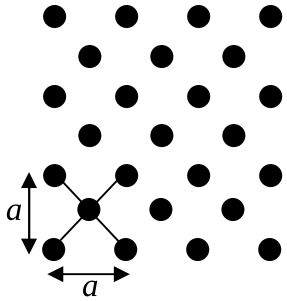
(d) Internal energy of the gas increases as its atoms have more space to move around

Q17. Particle A with angular momentum $j=\frac{3}{2}$ decays into two particles B and C with angular momenta j_1 and j_2, respectively. If $\left|\frac{3}{2},\frac{3}{2}\right\rangle_A = \sim\left|1,1\right\rangle_B \otimes \left|\frac{1}{2},\frac{1}{2}\right\rangle_C$, the value of $\sim$ is_____________

Q18. Far from the Earth, the Earth's magnetic field can be approximated as due to a bar magnet of magnetic pole strength $4\times10^{14}\ \text{Am}$. Assume this magnetic field is generated by a current carrying loop encircling the magnetic equator. The current required to do so is about $4\times10^{n}\ \text{A}$, where n is an integer. The value of n is ______.

(Earth's circumference: $4\times10^{7}\ m$)

Q19. The number of distinct ways the primitive unit cell can be constructed for the two dimensional lattice as shown in the figure is__________________.



Q20. A hydrogenic atom is subjected to a strong magnetic field. In the absence of spin-orbit coupling, the number of doubly degenerate states created out of the d-level is _________

Q21. A particle Y undergoes strong decay $Y \to \text{®}^- + \text{®}^-$. The isospin of Y is _________

Q22. For a complex variable z and the contour $c:|z|=1$ taken in the counter clockwise direction,

$$\frac{1}{2\text{®} i}\oint_C \left(z-\frac{2}{z}+\frac{3}{z^2}\right)dz = \_\_\_\_\_\_\_\_\_$$

Q23. Let p be the momentum conjugate to the generalized coordinate q. If the transformation

$$Q=\sqrt{2}q^m \cos p$$

$$P=\sqrt{2}q^m \sin p$$

is canonical, then $m=$_________

Q24. A conducting sphere of radius $1m$ is placed in air. The maximum number of electrons that can be put on the sphere to avoid electrical breakdown is about 7×10^n, where n is an integer. The value of n is ______________.

Assume:

Breakdown electric field strength in air is $|\vec{E}| = 3\times10^6\, V/m$

Permittivity of free space £$_0 = 8.85\times10^{-12}\, F/m$

Electron charge $e = 1.60\times10^{-19} C$

Q25. If a particle is moving along a sinusoidal curve, the number of degree of freedom of the particle is ____________

Q26 – Q55 carry two marks each.

Q26. The product of eigenvalues of $\begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$ is

(a) -1 (b) 1 (c) 0 (d) 2

Q27. Let $|e_1\rangle = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, |e_2\rangle = \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}, |e_3\rangle = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$. Let $S = \{|e_1\rangle, |e_2\rangle, |e_3\rangle\}$.

Let $\mathbb{R}^3$ denote the three dimensional real vector space. Which one of the following is correct?

(a) S is an orthonormal set

(b) S is a linearly dependent set

(c) S is a basis for $\mathbb{R}^3$

(d) $\sum_{i=1}^{3} |e_i\rangle\langle e_i| = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

Q28. $\hat{S}_x$ denotes the spin operator defined $\hat{S}_x = \frac{\hbar}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$. Which one of the following is correct?

(a) The eigenstates of spin operator $\hat{S}_x$ are $|\uparrow\rangle_x = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $|\downarrow\rangle_x = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$

(b) The eigenstates of spin operator $\hat{S}_x$ are $|\uparrow\rangle_x = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ -1 \end{pmatrix}$ and $|\uparrow\rangle_x = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \end{pmatrix}$

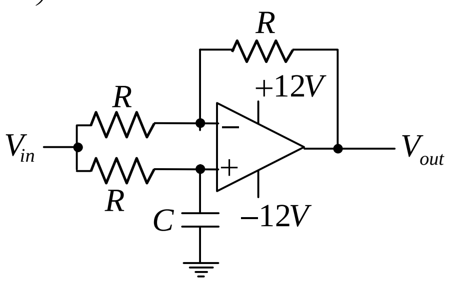
(c) In the spin state $\frac{1}{2}\begin{pmatrix} 1 \\ \sqrt{3} \end{pmatrix}$, upon the measurement of $\hat{S}_x$, the probability for obtaining $|\uparrow\rangle_x$ is

$\frac{1}{4}$

(d) In the spin state $\frac{1}{2}\begin{pmatrix} 1 \\ \sqrt{3} \end{pmatrix}$, upon the measurement of $\hat{S}_x$, the probability for obtaining $|\uparrow\rangle_x$ is

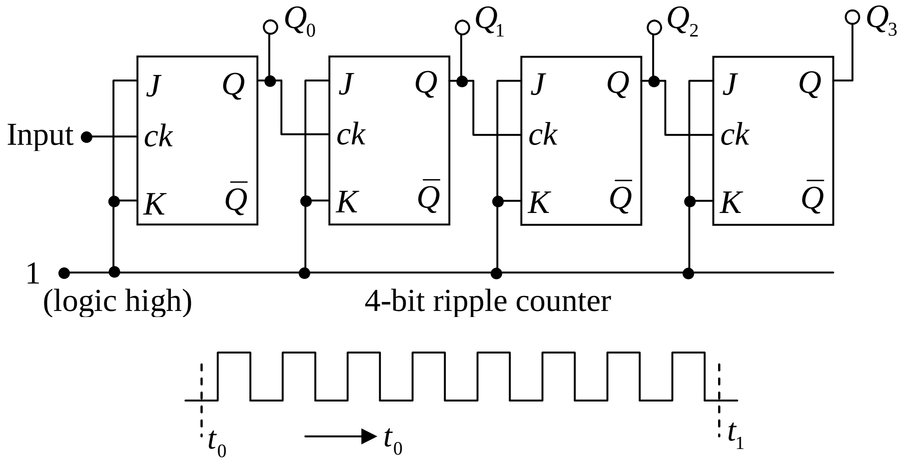
$\frac{2+\sqrt{3}}{4}$

Q29. The input voltage (V_{in}) to the circuit shown in the figure is $2\cos(100t)V$. The output voltage (V_{out}) is $2\cos\left(100t - \frac{®}{2}\right)V$. If $R = 1k\Omega$, the value of C (in «F)is



(a) 0.1 (b) 1 (c) 10 (d) 100

Q30. Consider a 4-bit counter constructed out of four flip-flops. It is formed by connecting the J and K inputs to logic high and feeding the Q output to the clock input of the following flip-flop (see the figure). The input signal to the counter is a series of square pulses and the change of state is triggered by the falling edge. At time $t = t_0$ the outputs are in logic low state $(Q_0 = Q_1 = Q_2 = Q_3 = 0)$. Then at $t = t_1$, the logic state of the outputs is



Input signal

(a) $Q_0 = 1, Q_1 = 0, Q_2 = 0$ and $Q_3 = 0$

(b) $Q_0 = 0, Q_1 = 0, Q_2 = 0$ and $Q_3 = 1$

(c) $Q_0 = 1, Q_1 = 0, Q_2 = 1$ and $Q_3 = 0$

(d) $Q_0 = 0, Q_1 = 1, Q_2 = 1$ and $Q_3 = 1$

Q31. Consider the Lagrangian $L = a\left(\frac{dx}{dt}\right)^2 + b\left(\frac{dy}{dt}\right)^2 + cxy$, where a, b and c are constants. If p_x and p_y are the momenta conjugate to the coordinates x and y respectively, then the Hamiltonian is

(a) $\frac{p_x^2}{4a} + \frac{p_y^2}{4b} - cxy$

(b) $\frac{p_x^2}{2a} + \frac{p_y^2}{2b} - cxy$

(c) $\frac{p_x^2}{2a} + \frac{p_y^2}{2b} + cxy$

(d) $\frac{p_x^2}{a} + \frac{p_y^2}{b} + cxy$

Q32. Which one of the following matrices does NOT represent a proper rotation in a plane?

(a) $\begin{pmatrix} -\sin\theta & \cos\theta \\ -\cos\theta & -\sin\theta \end{pmatrix}$

(b) $\begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$

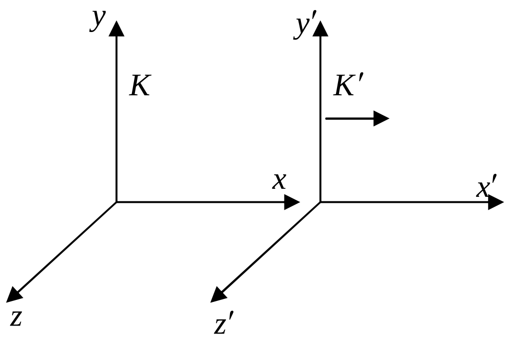
(c) $\begin{pmatrix} \sin\theta & \cos\theta \\ -\cos\theta & \sin\theta \end{pmatrix}$

(d) $\begin{pmatrix} -\sin\theta & \cos\theta \\ -\cos\theta & \sin\theta \end{pmatrix}$

Q33. A uniform magnetic field $\vec{B} = B_0\hat{y}$ exists in an internal frame K. A perfect conducting sphere moves with a constant velocity $\vec{v} = v_0\hat{x}$ with respect to this inertial frame. The rest frame of the sphere is K' (see figure). The electric and magnetic fields in K and K' are related as

$$\left.\begin{array}{ll}\vec{E}'_{\parallel} = \vec{E}_{\parallel} & \vec{E}'_{\perp} = \gamma\left(\vec{E}_{\perp} + \vec{v}\times\vec{B}\right) \\ \vec{B}'_{\parallel} = \vec{B}_{\parallel} & \vec{B}'_{\perp} = \gamma\left(\vec{B}_{\perp} - \dfrac{\vec{v}}{c^2}\times\vec{E}\right)\end{array}\right\}, \gamma = \frac{1}{\sqrt{1-(v/c)^2}}$$

The induced surface charge density on the sphere (to the lowest order in v/c) in the frame K' is



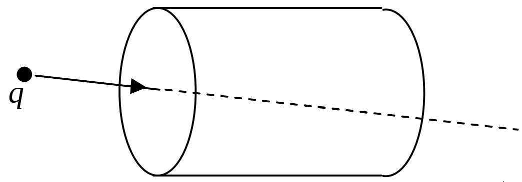
(a) maximum along z'

(b) maximum along y'

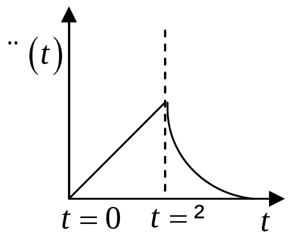
(c) maximum along x'

(d) uniform over the sphere

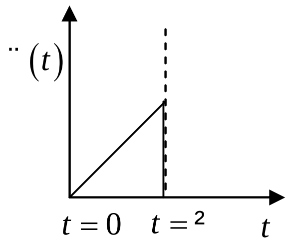
Q34. A charge q moving with uniform speed enters a cylindrical region in free space at $t = 0$ and exits the region at $t = \tau$ (see figure). Which one of the following options best describes the time dependence of the total electric flux $\Phi(t)$, through the entire surface of the cylinder?



(a)



(b)



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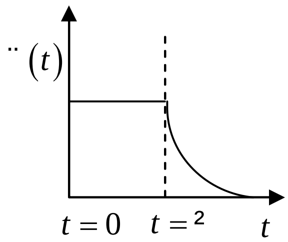
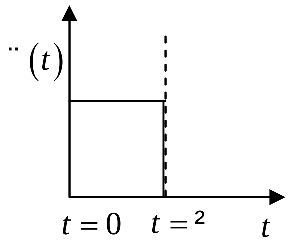


(d)



Q35. Consider a one-dimensional non-magnetic crystal with one atom per unit cell. Assume that the valence electrons (i) do not interact with each other and (ii) interact weakly with the ions. If n is the number of valence electrons per unit cell, then at $0\ K$,

(a) The crystal is metallic for any value of n

(b) The crystal is non-metallic for any value of n

(c) The crystal is metallic for even values of n

(d) The crystal is metallic for odd values of n

Q36. According to the Fermi gas model of nucleus, the nucleons move in a spherical volume of radius $R\,(=R_0 A^{\frac{1}{3}}$, where A is the mass number and R_0 is an empirical constant with the dimensions of length). The Fermi energy of the nucleus E_F is proportional to

(a) R_0^2 (b) $\frac{1}{R_0}$ (c) $\frac{1}{R_0^2}$ (d) $\frac{1}{R_0^3}$

Q37. Consider a two dimensional crystal with 3 atoms in the basis. The number of allowed optical branches (n) and acoustic branches (m) due to the lattice vibrations are

(a) $(n,m)=(2,4)$ (b) $(n,m)=(3,3)$

(c) $(n,m)=(4,2)$ (d) $(n,m)=(1,5)$

Q38. The internal energy U of a system is given by $U(S,V) =$ ª$V^{-2/3}S^2$, where ª is a constant of appropriate dimensions; V and S denote the volume and entropy, respectively. Which one of the following gives the correct equation of state of the system?

(a) $\frac{PV^{1/3}}{T^2}=\text{constant}$ (b) $\frac{PV}{T^{1/3}}=\text{constant}$ (c) $\frac{P}{V^{1/3}T}=\text{constant}$ (d) $\frac{PV^{2/3}}{T}=\text{constant}$

Q39. The potential energy of a particle of mass m is given by

$$U(x)=a\sin\left(k^2x-® /2\right),\qquad a>0,\ \ k^2>0$$

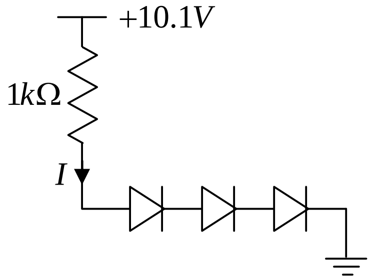
The angular frequency of small oscillations of the particle about $x=0$ is

(a) $k^2\sqrt{\frac{2a}{m}}$ (b) $k^2\sqrt{\frac{a}{m}}$ (c) $k^2\sqrt{\frac{a}{2m}}$ (d) $2k^2\sqrt{\frac{a}{m}}$

Q40. The radial wave function of a particle in a central potential is give by $R(r) = A\frac{r}{a}\exp\left(-\frac{r}{2a}\right)$, where A is the normalization constant and a is positive constant of suitable dimensions. If ¥a is the most probable distance of the particle from the force center, the value of ¥ is ____________

Q41. A free particle of mass M is located in a three-dimensional cubic potential well with impenetrable walls. The degeneracy of the fifth excited state of the particle is __________

Q42. Consider the circuit given in the figure. Let the forward voltage drop across each diode be $0.7V$. The current I (in mA) through the resistor is ____________.



Q43. Let $u^{«}$ denote the 4-velocity of a relativistic particle whose square $u^{«}u_{«} = 1$. If £$_{«¬°±}$ is the Levi-Civita tensor then the value of £$_{«¬°±}u^{«}u^{¬}u^{°}u^{±}$ is _________.

Q44. Consider a simple cubic monoatomic Bravais lattice which has a basis with vectors $\vec{r}_1 = 0, \vec{r}_2 = \frac{a}{4}(\hat{x}+\hat{y}+\hat{z})$, a is the lattice parameter. The Bragg reflection is observed due to the change in the wave vector between the incident and the scattered beam as given by $\vec{K} = n_1\vec{G}_1 + n_2\vec{G}_2 + n_3\vec{G}_3$, where $\vec{G}_1, \vec{G}_2$ and $\vec{G}_3$ are primitive reciprocal lattice vectors. For $n_1 = 3, n_2 = 3$ and $n_3 = 2$, the geometrical structure factor is __________

Q45. A plane electromagnetic wave of wavelength ª is incident on a circular loop of conducting wire. The loop radius is a($a <<$ ª). The angle (in degrees), made by the Poynting vector with the normal to the plane of the loop to generate a maximum induced electrical signal, is ___________

Q46. An electron in a hydrogen atom is in the state $n = 3, l = 2, m = -2$. Let $\hat{L}_y$ denote the y-component of the orbital angular momentum operator. If $\left(\Delta\hat{L}_y\right)^2 =$ ~$\hbar^2$, the value of ~ is_____________

Q47. A sinusoidal voltage of the form $V(t)=V_0\cos(\mu t)$ is applied across a parallel plate capacitor placed in vacuum. Ignoring the edge effects, the induced emf within the region between the capacitor plates can be expressed as a power series in μ. The lowest non-vanishing exponent in μ is ___________

Q48. If $x=\sum_{k=1}^{\infty} a_k \sin kx$, for $-® \le x \le ®$, the value of a_2 is_______

Q49. Let $f_n(x)=\begin{cases} 0, & x<-\frac{1}{2n} \\ n, & -\frac{1}{2n}<x<\frac{1}{2n} \\ 0, & \frac{1}{2n}<x \end{cases}$

The value of $\lim_{n\to\infty}\int_{-\infty}^{\infty} f_n(x)\sin x\,dx$ is________.

Q50. Consider the Hamiltonian $\hat{H}=\hat{H}_0+\hat{H}'$ where

$\hat{H}_0=\begin{pmatrix} E & 0 & 0 \\ 0 & E & 0 \\ 0 & 0 & E \end{pmatrix}$ and $\hat{H}'$ is the time independent perturbation given by

$\hat{H}'=\begin{pmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{pmatrix}$, where $k>0$. If, the maximum energy eigenvalues of $\hat{H}$ is $3eV$ corresponding to $E=2eV$, the value of k (rounded off to three decimal places) in eV is______________ check the question

Q51. A hydrogen atom is in an orbital angular momentum state $|l,m=l\rangle$. If $\vec{L}$ lies on a cone which makes a half angle 30^0 with respect to the z-axis, the value of l is __________

Q52. In the center of mass frame, two protons each having energy $7000\,\text{GeV}$, collide to produce protons and anti-protons. The maximum number of anti-protons produced is___________

(Assume the proton mass to be $1GeV/c^2$)

Q53. Consider a gas of hydrogen atoms in the atmosphere of the Sun where the temperature is $5800\,K$. If a sample from this atmosphere contains 6.023×10^{23} of hydrogen atoms in the ground state, the number of hydrogen atoms in the first excited state is approximately 8×10^{n}, where n is an integer. The value of n is __________.

(Boltzmann constant: $8.617\times10^{-5}\,eV/K$)

Q54. For a gas of non-interacting particles, the probability that a particle has a speed v in the internal v to $v+dv$ is given by

$$f(v)\,dv = 4® v^2 dv\left(\frac{m}{2® k_B T}\right)^{3/2} e^{-mv^2/2k_BT}$$

If E is the energy of a particle, then the maximum in the corresponding energy distribution in units of E/k_BT occurs at _________ (rounded off to one decimal place).

Q55. The Planck's energy density distribution is given by $u(µ) = \frac{\hbar µ^3}{®^2 c^3\left(e^{\hbar µ/k_BT} - 1\right)}$. At long wavelengths, the energy density of photons in thermal equilibrium with a cavity at temperature T varies as $T^{~}$, where ~ is ___________