PHYSICAL SCIENCES
PAPER I (PART 'B')

41. The resolution of a Michelson interferometer operating with a light source of 640 *nm* wavelength is

1. 1280 *nm*.
2. 640 *nm*.
3. 80 *nm*.
4. 1 *nm*.

42. When a terminal is at virtual ground, then

1. both current and voltage are zero.
2. only voltage will be zero.
3. only current will be zero.
4. both voltage and current are not zero.

43. Platinum resistor (PTR) and a thermistor(THR) are used to measure room temperature. Which of the following is true?

1. PTR offers more accuracy, THR more resolution.
2. PTR offers more resolution, THR more accuracy.
3. Both offer same accuracy, THR offers more resolution.
4. Both offer same resolution, PTR offers more accuracy.

44. A four bit A/D converter is used to convert an analog voltage of $8V$. The maximum error is

1. 0.5 *V*.
2. 1.0 *V*.
3. 2.0 *V*.
4. 0.25 *V*.

45. A voltage of 2300 volts is applied to a cylindrical counter with an anode wire of radius 0.01 *cm* and a cathode inner radius of 1.0 *cm*. The electric field at the anode surface is

1. 5×10^4 *V*/*cm*.
2. 5×10^3 *V*/*cm*.
3. 5×10^5 *V*/*cm*.
4. 5×10^2 *V*/*cm*.

46. A γ-ray of energy 1 *keV* is passed through a solid absorber of thickness 3 *cm* and mass attenuation coefficient 3 cm^2/g at temperature T_1. If the same absorber is melted at temperature T_2, the mass attenuation coefficient will be

1. $3\,(T_1/T_2)^2\ cm^2/g$.
2. $1/3\ cm^2/g$.
3. $3\ cm^2/g$.
4. $3\,(T_2/T_1)^2\ cm^2/g$.

47. Five panelists are required to elect a sixth member to the panel. If any of the panelists votes against a member, the member is disqualified. What would be the appropriate electronic circuit to be used in the electronic voting machine to implement the above rule?

1. XOR
2. XNOR
3. OR
4. AND

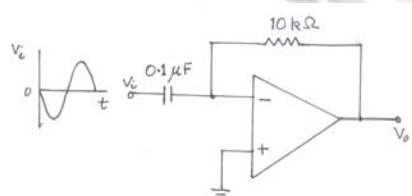
48. In an op-amp, when the input signal drives the output at a rate of voltage change greater than the slew rate, then the resulting signal

1. is enhanced.
2. is clipped .
3. is unaffected.
4. remains the same, but with 90^0 phase difference.

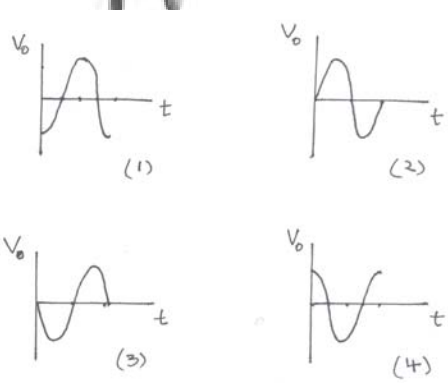
49. Sensitive experiments are often performed inside a metal enclosure known as a Faraday cage. Which of the following of Maxwell's equations governs the principle of operation of the cage?

1. $\vec{\nabla}.\vec{E} = \rho / E_0$
2. $\vec{\nabla}.\vec{B} = 0$
3. $\vec{\nabla} \times \vec{E} = -\partial\vec{B} / \partial t$
4. $\vec{\nabla} \times \vec{H} = \mu_0 \left[\vec{J} + \varepsilon_0 \dfrac{\partial \vec{E}}{\partial t} \right]$

50. Consider the following operational amplifier circuit with an input signal of frequency 10 *kHz*.



Which of the following represents the output waveform V_0 ?



51. For the ground state of a particle moving freely in a one-dimentional box $0 \le x \le L$ with rigid reflecting end-points, the uncertainty product (Δx) (Δp) is

1. $h/2$
2. $\sqrt{2}\,h$
3. $> h/2$
4. $h/\sqrt{3}$

52. Consider a system of two spin-half particles, in a state with total spin quantum number $S = 0$. The eigenvalue of the spin Hamiltonian $H = A\,\vec{S}_1.\vec{S}_2$ (A is a positive constant) in this state is

1. $A h^2/4$
2. $-A h^2/4$
3. $3A h^2/4$
4. $-3A h^2/4$

53. The energy of a 200 nm photon is
1. 0.01 eV
2. 100 eV
3. 10 eV
4. 1 eV

54. The wave function $\psi(\vec{r})$ of a particle moving in three-dimensional space has the physical dimensions of

1. $(\text{Length})^{-3/2}$
2. $(\text{Length})^{3/2}$
3. $(\text{Length})^{-1}$
4. (Length)

55. The eigenvalues of the Pauli spin matrix $\sigma_y = \begin{pmatrix} \theta & -i \\ i & 0 \end{pmatrix}$ are

1. $+1, +1$
2. $+1, -1$
3. $-i, +i$
4. $+i, +i$

56. The ground state energy of a particle in an infinite square-well potential of width L is E. If the width of the wall is reduced to $L/2$, then the ground state energy becomes

1. $2E$
2. $E/2$
3. $4E$
4. $E/4$

57. The classical definition of the orbital angular momentum of a particle is $\vec{L} = \vec{r} \times \vec{p}$. The corresponding quantum mechanical definition for the orbital angular momentum operator (taking into account the fact that $\vec{r}$ and $\vec{p}$ do not commute with each other) is

1. $\vec{L} = \vec{r} \times \vec{p}$
2. $\vec{L} = \frac{1}{2}[(\vec{r} \times \vec{p}) + (\vec{p} \times \vec{r})]$
3. $\vec{L} = \frac{1}{2i}[(\vec{r} \times \vec{p}) - (\vec{p} \times \vec{r})]$
4. $\vec{L} = \frac{\vec{r}}{r}(\vec{p} \times \vec{r})$

58. Given the Hamiltonian $\hat{H} = \hat{H}_0 + i\hat{T}$, where $\hat{H}_0$ and $\hat{T}$ are hermitian operators, which of the following statements are correct?

1. $\hat{H}$ is a hermitian operator and the total probability is conserved
2. $\hat{H}$ is a hermitian operator and the total probability is <u>*not*</u> conserved
3. $\hat{H}$ is <u>*not*</u> a hermitian operator and the total probability is conserved
4. $\hat{H}$ is <u>*not*</u> a hermitian operator and the total probability is <u>*not*</u> conserved

59. The Hamiltonian of a three-level system is

$$H = a\begin{pmatrix} 2 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

The energy eigenvalues are

1. $2a,\ a, -a$
2. $2a, a, 0$
3. $2a, 0, 0$
4. $2a, a, a$

60. The ground state energy of a particle in the one-dimensional potential

$$V(x) = \begin{cases} \frac{1}{2} m w^2 x^2 & \text{for } x > 0 \\ \infty & \text{for } x < 0 \end{cases}$$

is equal to

1. $h\omega$
2. $\frac{3}{2}h\omega$
3. $2h\omega$
4. $\frac{5}{2}h\omega$

61. Let k be the wave number of the incident plane wave in a scattering experiment. If the scattering is purely a p-wave with the phase shift $\delta_1 = \pi/4$, then the total scattering cross-section is

1. $2\pi/k^2$
2. $6\pi/k^2$
3. 0
4. k^2

62. Plane polarized light will be rotated when it is passed through a solution of

1. $Na\ Cl\ O_3$
2. $CH\ Cl\ F_2$
3. $HC\ Br\ Cl\ F$
4. $Br\ CH_3$

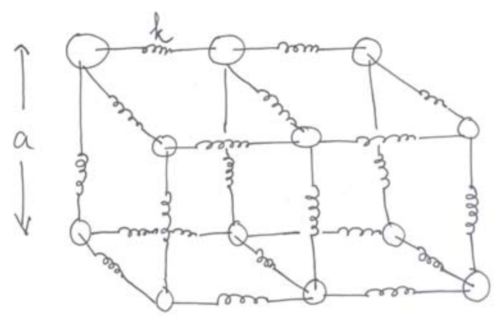
63. The specific heat of silicon monoxide at high temperatures, as compared to silicon dioxide, is

1. larger .
2. smaller.
3. equal.
4. dependent on other parameters not specified here.

64. You are shown a spectrum consisting of a series of equally spaced lines. This could be

1. the rotational spectrum of CO.
2. the vibrational spectrum of N_2.
3. the NMR spectrum of CH_4.
4. the Mossbauer spectrum of Fe_3O_4.

65. The figure below shows a "bead-spring" model of a simple cubic crystalline lattice. The springs have spring constants k and the lattice spacing is a. For this model, the shear modulus governing displacements along the x - direction with a gradient along the z - direction is:



1. 0.
2. k / a.
3. $k / 6a$.
4. k / a^2.

66. The ratio $\kappa / \sigma T$ (where κ is the thermal conductivity, σ is the electrical conductivity and T is the temperature) for metals

1. is strongly dependent on the number density of the charge carriers.
2. is independent of the temperature T.
3. varies widely from one metal to another .
4. is approximately independent of the particular metal.

67. Let $U(x) = \frac{1}{2} ax^2 - bx^3 + cx^4$ be the energy cost of stretching the unit cell of a certain crystal by an amount x, (a, b and c are constants with a and c being positive). Then at temperature T the coefficient of linear thermal expansion (to first order in b and zeroth order in c) is proportional to

1. a^2b.
2. b / a^2.
3. a^2 / b.
4. $1 / ba^2$.

68. The dispersion relation for spinwaves in a three dimensional Heisenberg ferromagnet is $\omega = Ak^2$, where ω is the frequency, k is the wave number, and A is a constant. The contribution of spin waves to the specific heat, at low temperatures T, is proportional to

1. $T^{2/3}$
2. $T^{3/2}$
3. T^2
4. $T^{1/2}$

69. For a one- dimensional monatomic lattice with lattice constant a the normal modes satisfy the relation

1. $\omega(q) = \omega\left(q + \frac{2\pi}{a}\right)$
2. $\omega(q) = \omega\left(q + \frac{\pi}{2a}\right)$
3. $\omega(q) = \omega\left(q + \frac{\pi}{a}\right)$
4. $\omega(q) = \omega\left(q + 2\pi a\right)$

70. Consider a gas of non-interacting electrons at T=0. If the electrons (of mass m) are replaced by neutrons (of mass M) keeping the density $n = N/V$ the same, the Fermi energy ε_F is changed by a factor

1. $\frac{M}{m}$.
2. $\left(\frac{M}{m}\right)^{2/3}$.
3. $\left(\frac{M}{m}\right)^{3/2}$.
4. $\frac{m}{M}$.

71. For a one- dimensional Debye solid, the lattice specific heat at low temperatures T will be proportional to

1. $T^{1/2}$.
2. T.
3. $T^{3/2}$.
4. T^2.

72. The dispersion relation for a certain type of excitation is given by $\omega = A\,k^a$, where *A and* $a > 0$ are constants. For these excitations, the group velocity is less than the phase velocity when

1. $a = 1$.
2. $a = \sqrt{2}$.
3. $a < 1$.
4. $a \geq 2$.

73. ^{10}Be in its first excited state has spin–parity 2^+. It gets de-excited to the ground state, which has spin parity 0, by γ–emission. The multipoles carried by γ are

1. *E*2.
2. *M*2.
3. *E*2, *M*2.
4. *E*4.

74. Two protons are placed at a distance of about 10^{-13} cm from each other. The ratio of the strength of strong and electromagnetic forces between them is roughly

1. 10.
2. 1.
3. 10^3.
4. 10^{-5}.

75. Which of the following is not an acceptable potential for the deuteron ($V_0 > 0$; k , $\mu > 0$)?

1. $V(r) = -V_0\, e^{-\mu r}$;
2. $V(r) = -V_0$ for $r < R_0$
   $= 0$ for $r > R_0$
3. $V(r) = +\frac{1}{2}kr^2$
4. $V(r) = \frac{-V_0}{1+e^{\mu r}}$

76. The total cross-section for $\mu^+ \mu^- \to e^+ e^-$ at very high values of the centre of mass energies, $\sqrt{s} >> m_e$, is expected to behave as

1. $\frac{e^2}{s^2}$.
2. $\frac{e^4}{s^2}$.
3. constant.
4. $\frac{e^4}{s}$.

77. Which of the following is true for β-decay of the neutron? The process

1. violates both parity and charge conjugation symmetry.
2. violates parity but conserves charge conjugation symmetry.
3. conserves parity but violates charge conjugation symmetry.
4. conserves both parity and charge conjugation symmetry.

78. The Coulomb repulsion term which contributes to the binding energy of a nucleus ^AX_Z is proportional to

1. Z.
2. Z^2.
3. $Z(Z-1)$.
4. It is independent of Z.

79. In the quark model, the state of π^+ is given by $|u\bar{d}>$. The states for π^- and π^0 are then given by

1. $|\bar{u}\, d\rangle; \frac{1}{\sqrt{2}}|u\bar{u} + d\bar{d}\rangle$.
2. $|\bar{u}\, d\rangle; \frac{1}{\sqrt{2}}|u\bar{u} - d\bar{d}\rangle$.
3. $|\bar{u}d\rangle; |u\bar{u}\rangle$.
4. $|\bar{u}d\rangle; |d\bar{d}\rangle$.

80. The neutral pion π^0 at rest decays into two photons. One of the photons is right circularly polarized. The other photon is

1. also right circularly polarized.
2. left circularly polarized.
3. unpolarized.
4. plane polarized.

81. A 100 MeV proton and a 100 MeV alpha particle are detected in the same detector. What is the ratio of energy loss per unit path length i.e. $\left(\frac{dE}{dx}\right)_p : \left(\frac{dE}{dx}\right)_\alpha$?

1. 1:1.
2. 1:2.
3. 1:4.
4. 1:16.

82. The number of ways in which 5 identical bosons can be distributed in 4 states is

1. $\frac{8!}{5!\,3!}$
2. $\frac{9!}{5!\,4!}$
3. $\frac{9!}{4!\,4!}$
4. $\frac{8!}{4!\,4!}$

83. An adiabat in the PV-plane is a curve of

1. constant temperature
2. constant entropy
3. constant pressure
4. constant volume

84. The standard deviation of the energy of a system in the canonical ensemble is equal to

1. $\sqrt{C_v}$

2. $k_B T^2 C_v$

3. $\sqrt{k_B T^2 C_v}$

4. $\sqrt{k_B T C_v}$

85. Blackbody radiation is enclosed inside a spherical cavity of radius r at a temperature T. What would be the temperature of the enclosure if the radius expands to $2r$ adiabatically ?

1. $T/2$

2. T

3. $T/\sqrt{2}$

4. $2T$

86. Which of the following is *not* a periodic function of θ ?

1. $\sin\theta + \pi\cos\theta$

2. $\sin(\pi\theta) + \cos(\pi\theta)$

3. $\sin\theta + \cos(\pi\theta)$

4. $\sin\theta + \cos(\theta + \pi)$

87. A given $(n \times n)$ nilpotent matrix A satisfies the equation $A^k = 0$ for $1 < k < n$. Therefore,

1. exactly k eigenvalues of A must be zero.
2. exactly $(n-k)$ eigenvalues of A must be zero.
3. every eigenvalue of A is zero.
4. A can have $(n-1)$ non-zero eigenvalues.

88. The Legendre polynomial $P_n(x)$, where $-1 \le x \le +1$

1. is singular at $x = \pm 1$
2. satisfies $\int_{-1}^{1} dx\, P_n^2(x) = 1$
3. satisfies $\int_{-1}^{1} dx\, P_n(x) = 0$ for $n \ge 1$
4. is always an even function of x

89. The residue of e^{2/z^2} at $z = 0$ is

1. 0
2. ∞
3. $2\pi i$
4. 2

90. The Newton - Raphson iteration formula for the square-root of the real number $A - 5$ is

1. $x_{n+1} = \dfrac{x_n^2 - A + 5}{2x_n}$
2. $x_{n+1} = \dfrac{x_n^2 + A - 5}{2x_n}$
3. $x_{n+1} = x_n - \dfrac{x_n}{\sqrt{A-5}}$
4. $x_{n+1} = x_n - \dfrac{1}{\sqrt{A-5}}$

91. The value of the integral $\int_0^\infty \left(4x^2 - 2\right)^2 e^{-x^2}\, dx$ is

1. $4\sqrt{\pi}$

2. $8\sqrt{\pi}$

3. $4\ \pi$

4. $8\ \pi$

92. If $\vec{A}$ and $\vec{B}$ are two unit vectors and $\theta \neq 0$ is the angle between them, then

1. $\sin\ \theta = \frac{1}{2}\left|\vec{A} + \vec{B}\right|$

2. $\sin\ \theta = \frac{1}{2}\left|\vec{A} - \vec{B}\right|$

3. $\sin\ \frac{\theta}{2} = \ \frac{1}{2}\left|\vec{A} - \vec{B}\right|$

4. $\sin\ \frac{\theta}{2} = \ \frac{1}{2}\left|\vec{A} + \vec{B}\right|$

93. The number of independent components of a symmetric and an antisymmetric tensor of rank 2 (in 3-dimensions) are, respectively,

1. 6, 6
2. 9, 3
3. 6, 3
4. 3, 6

94. The trapezoidal, Simpson's 1/3 and Simpson's 3/8 rules are exact for polynomials of order

1. 1, 2, 3 respectively

2. 1, 3, 3 respectively

3. 1, 3, 4 respectively

4. 2, 3, 4 respectively

95. For the Bessel equation, $x^2 \frac{d^2 y}{dx^2} + x \frac{dy}{dx} + (x^2 - n^2) y = 0$, where n is an integer, the maximum number of linearly independent solutions, well-defined at $x = 0$ is

1. zero
2. one
3. two
4. three

96. Let E_1, E_2, E_3 be the first three energy levels of a hydrogen atom. Consider the ratio $(E_3 - E_2) / (E_2 - E_1)$. Neglecting the fine structure condition this ratio is approximately equal to

1. $\frac{27}{5}$
2. $\frac{1}{27}$
3. $\frac{27}{4}$
4. $\frac{5}{27}$

97. The rotational energy levels of a rigid diatomic molecules are given by $E_J = B_e J(J+1)$ where J is the rotational quantum number and B_e is a the constant. The rotational absorption spectrum of the molecules therefore consists of

1. one resonance line
2. lines that are equally spaced
3. lines where the spacing increases with frequency
4. lines where the spacing decreases with frequency

98. For an atom with two energy levels placed in a cavity containing blackbody radiation, the ratio of the probabilities for spontaneous emission and stimulated emission is given by

$\frac{A}{B} = \frac{8\pi h v^3}{c^3}$, where A and B are the corresponding Einstein coefficients and v is the frequency of the photon emitted. The probability of spontaneous emission

1. is independent of the energy difference between the two levels.
2. increases with the energy difference between the two levels.
3. decreases with the energy difference between the two levels.
4. is zero.

99. Consider a parallel plate capacitor connected to an AC voltage source (as shown in Fig.1). *A conducting* slab is introduced in the space between the plates from above (as shown in fig.2).

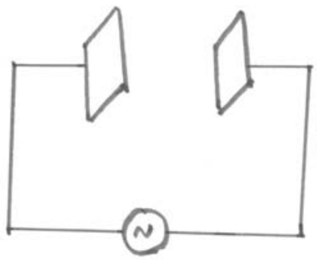


Fig. 1

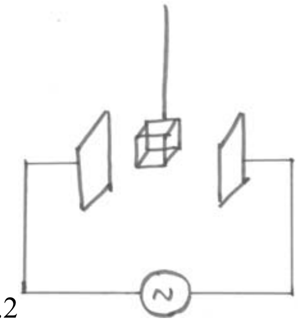


Fig.2

The capacitance of the parallel plate capacitor

1. goes to zero.
2. increases to a finite value.
3. decreases to a non-zero value.
4. becomes infinite.

100. The volume of a thermodynamic system increases irreversibly by an incremental amount δ V. If P is the pressure, the work done *on* the system is

1. $\delta W = P\delta V$
2. $\delta W = -P\delta V$
3. $\delta W < -P\delta V$
4. $\delta W > -P\delta V$

101. Two localized non-interacting spin 1/2 magnetic ions of magnetic moment μ are placed in an external magnetic field H, at temperature T. If $k_B T >> \mu H$, then the entropy of the system is, to a good approximation

1. $S = k_B \ln 2$
2. $S = 2k_B \ln 2$
3. $S = 3k_B \ln 2$
4. $S = 4k_B \ln 2$

102. A thermodynamic system is classified as closed if it can

1. exchange energy with its surroundings , but not matter
2. exchange both energy and matter with its surroundings
3. exchange neither energy nor matter with its surroundings
4. exchange only matter, but not energy, with its surroundings

103. Consider an elastic string of length L under tension τ at temperature T. Let U and S be its internal energy and entropy, respectively. Then the conjugate pairs of thermodynamic variables are

1. (τ, T) and (L, S)
2. (L, τ) and (T, S)
3. (T, L) and (τ, U)
4. (L, S) and (T, U)

104. At 100ºC, water vapour and liquid water coexist in thermodynamic equilibrium in a closed container. If μ and S represent the chemical potential and entropy respectively, then at the interface

1. $\mu_{\text{vapour}} = \mu_{\text{liquid}}$
2. $S_{\text{vapour}} = S_{\text{liquid}}$
3. $S_{\text{vapour}} < S_{\text{liquid}}$
4. $\mu_{\text{vapour}} > \mu_{\text{liquid}}$

105. A system in thermal equilibrium consists of subsystems A and B that interact only weakly with each other. If Z_A and Z_B are the canonical partition functions of A and B respectively, the partition function of the total system is given, to a good approximation, by

1. $Z_A + Z_B$
2. Z_A / Z_B
3. $Z_A - Z_B$
4. $Z_A Z_B$

106. Consider an infinite horizontal surface with fixed surface charge density σ, where $\hat{n}$ is the upward normal to the surface. If an electric field $\vec{E}_b = E\hat{n}$ is applied from below, the electric field $\vec{E}_a$ in the region above the surface is

1. $\vec{E}_a = \vec{E}_b - \frac{\sigma}{2\varepsilon_0}\hat{n}$
2. $\vec{E}_a = \vec{E}_b + \frac{\sigma}{2\varepsilon_0}\hat{n}$
3. $\vec{E}_a = \vec{E}_b - \frac{\sigma}{\varepsilon_0}\hat{n}$
4. $\vec{E}_a = \vec{E}_b + \frac{\sigma}{\varepsilon_0}\hat{n}$

107. A charged particle is travelling in the positive x-direction with a constant velocity. An observer located at a point P on the y-axis observes the electric field due to this charge. Let $\hat{e}$ (t) be the unit vector along the electric field at any time t, and $\hat{n}$ (t) the unit vector in the direction of the position vector of the charge with respect to the observer. Then

1. $\hat{e}(t)$ lags behind $\hat{n}(t)$
2. $\hat{e}(t)$ leads $\hat{n}(t)$
3. $\hat{e}(t)$ is always in the same direction as $\hat{n}(t)$
4. $\hat{e}(t)$ is always perpendicular to $\hat{n}(t)$

108. A current carrying loop lying in the plane of the paper is in the shape of an equilateral triangle of side a. It carries a current I in the clockwise sense. If $\hat{k}$ denotes the outward normal to the plane of the paper, the magnetic moment $\vec{m}$ due to the current loop is

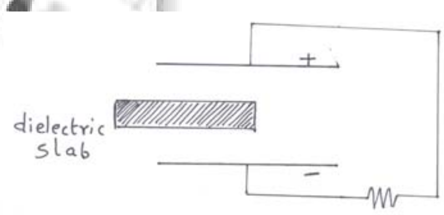
1. $\vec{m} = a^2 I \hat{k}$
2. $\vec{m} = -\frac{1}{2} a^2 I \hat{k}$
3. $\vec{m} = \frac{\sqrt{3}}{2} a^2 I \hat{k}$
4. $\vec{m} = -\frac{\sqrt{3}}{4} a^2 I \hat{k}$

109. Consider an infinite line charge with linear charge density λ. At a distance r from the line, the electrostatic potential has the form

1. $\frac{\lambda a}{4\pi\varepsilon_0 r}$.
2. $\frac{\lambda}{4\pi\varepsilon_0} \exp(-r/a)$
3. $\frac{\lambda}{4\pi\varepsilon_0} \ln\left(r/a\right)$
4. $\frac{\lambda}{4\pi\varepsilon_0} \frac{r}{a}$

where a is a constant with dimension of length.

110. A thin dielectric slab is slowly introduced partially between the plates of a charged parallel plate capacitor, as shown in the figure.



Which of the following is true?

1. The slab is pushed out of the region between the capacitor plates.
2. The slab is sucked into the region between the capacitor plates.
3. The slab moves towards the positively charged plate.
4. The slab moves towards the negatively charged plate.

111. An electric point charge $+q$ is placed at the point (1, 1) of the *xy*-plane in which two grounded semi-infinite conducting plates along the positive *x* and *y*-axes meet (see figure). The electric potential in the positive quadrant at a large distance *r* goes as

1. $V(r) \sim r^{-1}$
2. $V(r) \sim r^{-2}$
3. $V(r) \sim r^{-3}$
4. $V(r) \sim r^{-4}$

112. In a given frame of reference, it is found that the electric field $\vec{E}(\vec{r},t)$ and the magnetic field $\vec{B}(\vec{r},t)$ are perpendicular to each other at all points, *i.e.* $\vec{E}(\vec{r},t)\cdot\vec{B}(\vec{r},t)=0$. If the fields observed in any other inertial frame are $\vec{E}'$ and $\vec{B}'$, then

1. $\vec{E}' \,//\, \vec{B}'$ at all points.
2. $\vec{E}'\cdot\vec{B}' < 0$ at all points.
3. $\vec{E}'\cdot\vec{B}' > 0$ at all points.
4. $\vec{E}'\cdot\vec{B}' = 0$ at all points.

113. Consider the $(n \times n)$ matrix *A* with every element equal to unity. Which of the following statement is correct ?

1. The eigenvalues of *A* are all equal to unity.
2. All the eigenvalues of *A* are zero.
3. The largest eigenvalue of *A* is *n*.
4. *A* cannot be diagonalised by a similarity transformation.

114. The total energy *E* of a particle of mass *m* executing small oscillations about the origin along on the *x*-direction is given by

$$E = \frac{1}{2}mv^2 + V_0 \cosh\left(\frac{x}{L}\right),$$

where V_0 and *L* are positive constants. The time period *T* of oscillation is

1. $T = \frac{1}{2\pi}\sqrt{\frac{m}{V_0}}$.
2. $T = 2\pi\sqrt{\frac{L}{m}}$.
3. $T = \pi L\sqrt{\frac{m}{E}}$.
4. $T = 2\pi\sqrt{\frac{mL^2}{V_0}}$.

115. A canonical transformation in classical Hamiltonian dynamics

1. cannot be made if there is more than one degree of freedom.
2. leaves the canonical Poisson bracket relations unchanged.
3. can only be made for the cartesian components of the coordinates and momenta.
4. cannot be time-dependent.

116. The motion of a particle of mass m is described in a non-inertial frame of reference that is rotating with a uniform angular velocity $\vec{\omega}$. If $\vec{r}$ denotes the position of the particle in the non-inertial frame

1. the centrifugal force on the particle is $-m\omega^2\vec{r}$
2. the centrifugal force on the particle is $-m\vec{\omega}\times(\vec{\omega}\times\vec{r})$.
3. the Coriolis force on the particle is $-m\left(\vec{\omega}\times\frac{d\vec{r}}{dt}\right)$
4. the Coriolis force on the particle $-2m\omega^2\vec{r}$

117. The Lagrangian of a particle of mass m moving in a central potential $V(r)$ is

$$L=\frac{1}{2}m\left(\dot{r}^2+r^2\dot{\theta}^2+r^2\sin^2\theta\,\dot{\varphi}^2\right)-V(r)$$

1. θ is a cyclic coordinate.
2. θ and φ are cyclic coordinates.
3. φ is a cyclic coordinate.
4. r is a cyclic coordinate

118. A relativistic particle of rest mass m_0 is moving with a speed v. The value of v at which its kinetic energy is equal to its rest energy is

1. $v = c/2$
2. $v = c/4$
3. $v = c/\sqrt{2}$
4. $v = 2\left(\sqrt{2}-1\right)c$

119. An asymmetric rigid body has three distinct principal moments of inertia, with $I_x < I_y < I_z$. If we consider rotation with uniform angular velocity about the x, y and z axes, respectively, then the motion is

1. stable about the y-axis, but not about the x and z axes.
2. stable about the x and y axes, but not about the z-axis.
3. stable about the y and z axes, but not about the x axis.
4. stable about the x and z axes, but not about the y-axis.

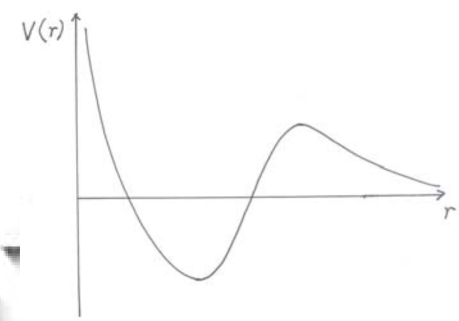
120. The constant acceleration due to gravity on the surface of a planet whose mass is twice the mass of Earth is found to be the same as the constant acceleration due to gravity on the surface of Earth. If R_e is the radius of Earth, then the radius of the planet must be

1. $2R_e$
2. $R_e/2$
3. $4R_e$
4. $\sqrt{2}\, R_e$

121. A particle of electric charge $+q$ and mass m is fired at a nucleus of charge $+Q$ and mass M in a Rutherford scattering experiment. In the center of mass frame,

1. the total energy, the total angular momentum and the total linear momentum are all conserved.
2. the total energy and the total angular momentum are conserved, but not the total linear momentum
3. the total energy is conserved, but not the total angular momentum and the total linear momentum
4. only the total electric charge is conserved, and no other quantity is conserved

122. A particle moves in the central potential $V(r)$ shown in the figure below



Which of the following statements is true?

1. Both a stable circular orbit and an unstable circular orbit are possible
2. Only a stable circular orbit is possible
3. Only an unstable circular orbit is possible
4. No circular orbit is possible

123. A particle of mass m is thrown upwards from the surface of the Earth with initial velocity components u_x and u_y along the horizontal and vertical directions respectively. The trajectory, therefore is given by $x(t) = u_x t$, $y(t)=u_y t - \frac{1}{2} g t^2$. The instant of time at which the acceleration and velocity vectors are perpendicular to each other is given by

1. u_x/g
2. $|u_x - u_y|/g$
3. $(u_x + u_y)/g$
4. u_y/g

124. The Lagrangian of a particle of mass m moving in two dimension is

$$L = \frac{1}{2} m(\dot{x}^2 + \dot{y}^2) - \frac{1}{2} k (x^2 + y^2)$$

If the particle has a finite angular momentum *l* about the origin, then we may conclude that it executes

1. oscillatory motion about the origin $r = 0$
2. periodic motion with a constant value of r
3. oscillatory motion along the x-axis
4. oscillatory motion along the y-axis

125. A particle moves in one dimension in a potential $V(x) = x^2/2 + x^3/3$, in suitable units. If E is the total energy of the particle, then the motion is

1. always bounded if $0 \le E \le \frac{1}{6}$
2. always unbounded if $0 \le E \le \frac{1}{6}$
3. always bounded if $E < 0$
4. bounded if $0 \le E \le \frac{1}{6}$ and the initial position satisfies $-1 < x(0) < \frac{1}{2}$

126. Let A and B be the Hermitian operators corresponding to two physical observables of a system, such that $[A, B] \neq 0$. We may conclude *in general* that

1. the uncertainty product is always $(\Delta A)(\Delta B) > \frac{h}{2}$.
2. the system can never be in a state in which $(\Delta A)(\Delta B) = 0$.
3. neither A nor B can have any eigenstates.
4. A and B *may* have one or more common eigenstate(s), but not a complete set of these.

127. The electronic configuration of the ground state of the Na atom is $^2S_{1/2}$. This implies that

1. $S = 2$, $L = 0$, $J = 2$
2. $S = 0$, $L = 1/2$, $J = 1/2$
3. $S = 1/2$, $L = 0$, $J = 1/2$
4. $S = 0$, $L = 2$, $J = 2$

128. The mirrors of a laser cavity are separated by a distance L. If T is the time taken by the light to travel from one mirror to the other and back, the mode separation is

1. $\frac{1}{T}$
2. $\frac{2}{T}$
3. $\frac{1}{2T}$
4. $\frac{1}{\sqrt{2}\,T}$

129. A semiconductor diode is employed for rectification of an alternating voltage of 10V and a current of 1A. The forward voltage on the diode, after the system has been in operation for several hours of power dissipation,

1. does not change
2. increases by ~ 100 mV
3. increases by ~1 mV
4. degreases by ~ 100 mV

130. The maximum efficiency of an ideal class B amplifier is

1. 87.5%
2. 50%
3. 68.5%
4. 78.5%

131. A free electron gas has DC electrical conductivity $\sigma_0 = \frac{ne^2\tau}{m}$ where n is the number density of carriers, e is the charge of the carriers, τ is the relaxation time and m is the effective mass of the carriers. Assuming that there is only one relaxation time, the AC conductivity at frequency ω is modeled by

1. $(1 - i\omega\tau)\sigma_0$
2. $\frac{\sigma_0}{1+\omega^2\tau^2}$
3. $(1 + i\omega\tau)\sigma_0$
4. $\frac{\sigma_0}{1 - i\omega\tau}$

132. A proton and a neutron are both subject to a uniform magnetic field. Which of the following is true?

1. Both particles undergo Larmor precession because they have non-zero intrinsic magnetic moments.
2. The neutron does not precess because its intrinsic magnetic moment is zero
3. The proton does not precess because its intrinsic magnetic moment is zero.
4. Both the particles precess and the direction of the precession is the same for the two particles

133. The Van der Waals equation of state for 1 mole of a gas is

$$\left(P+\frac{a}{V^2}\right)(V-b)= RT$$

where a and b are constants. If U is the internal energy of n moles of this gas, then $\left(\frac{\partial U}{\partial V}\right)_T$ is

1. zero
2. $\frac{a}{\left(\frac{V}{n-b}\right)^2}$
3. $\left(\frac{a}{nV}\right)^2$
4. $\frac{a}{(V/\ n)^2}$

134. If in interior of a unit sphere we have $\vec{\nabla}.\vec{J}$ = a positive constant, where $\vec{J}$ is the current density then we may conclude that;

1. according to Gauss' theorem, the charge contained in the unit sphere is constant in time
2. according to Gauss' theorem, charge is flowing into the unit sphere
3. according to the continuity equation, the charge density within the unit sphere must necessarily be uniform
4. according to the continuity equation, the change density inside the unit sphere diminishes with time

135. Choose the correct statement from the following:

1. The magnetic field $\vec{B}$ is a vector and not a pseudovector.

2. $\vec{E}.\vec{B}$ is a scalar and not a pseudoscalar.

3. $\vec{E}\times\vec{B}$ is a pseudovector.

4. The magnetic vector potential $\vec{A}$ *is a* pseudovector.

136. Given any arbitrary electric and magnetic fields $\vec{E}(\vec{r},t)$ *and* $\vec{B}(\vec{r},t)$, it is always possible to choose the scalar potential $\phi\ (\vec{r},t)$ and vector potential $\vec{A}(\vec{r},t)$ such that

1. $\vec{A}(\vec{r},t)$ is identically zero.

2. $\phi\ (\vec{r},t)$ is identically zero.

3. $\left|\vec{A}\ (\vec{r},t)\right|$ is any given non-zero constant.

4. the conditions $\nabla.\vec{A}=0$ and $\frac{1}{c}\frac{\partial\phi}{\partial t}+\nabla.\vec{A}=0$ are simultaneously satisfied.

137. In a certain region R, Maxwell's equations for the electric and magnetic fields are given by

$$\nabla\cdot\vec{E}=0,\ \nabla\cdot\vec{B}=0,\ \nabla\times\vec{E}=-\frac{\partial\vec{B}}{\partial t},\ \nabla\times\vec{B}=\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}.$$

We may conclude that:

1. Both the scalar and the vector potential are necessarily constant in the region R.

2. The electric field $\vec{E}$ and the magnetic field $\vec{B}$ must necessarily be uniform in R.

3. There are no sources for electric charges and currents in R.

4. The electric field $\vec{E}$ is necessarily perpendicular to the magnetic field $\vec{B}$ at every point in R.

138. The sum of

$$1-\frac{\pi^2}{2!\ 4^2}+\frac{\pi^4}{4!\ 4^4}-\frac{\pi^6}{6!\ 4^6}+\cdots \quad \text{is}$$

1. not convergent
2. $\frac{\pi}{2}$
3. $\frac{\pi}{\sqrt{2}}$
4. $\frac{1}{\sqrt{2}}$

139. Consider the alpha-decay reaction

$Po_{84}^{210} \rightarrow Pb_{82}^{206} + He_2^4$

where atomic masses are

m(Po) = 210.0483 amu
m(Pb) = 206.0386 amu
m(He) = 4.0039 amu
1 amu = 931.141 MeV.

The kinetic energy of the alpha particle will be
1. 5.4 keV.
2. 2.7 keV.
3. 5.4 MeV.
4. 10.8 MeV

140. Consider the operators a and a^+, satisfying the commutation relation $[a, a^+] = I$, the unit operator. There are no normalisable eigenstates of the operator

1. $a^+ a$
2. a
3. a^+
4. $(a^+ a)^2$