Entrance Examination, 2019

HCU (Ph.D.) PHYSICS

Marks: 70 **Time: 2:00 Hours**

1. This Question Paper has two parts: **PART - A** and **PART - B**
2. **PART - A** consists of **20** objective type questions related to Research Methods.
3. **PART - B** consists of **20** objective type questions related to Physics.
4. All questions carry 1.75 marks each. **There is no negative marking**
5. Only Scientific Calculators are permitted. Mobile phone based calculators are not permitted. Logarithmic tables are not allowed.

PART - A

Q1. From a group of 4 scientists and 3 engineers, the number of ways of forming a committee of 5 members such that there are at least 3 scientists in the committee is

(a) 10 (b) 12 (c) 15 (d) 20

Q2. The missing number in the series $0, 7, 26, \_\_, 124$ is

(a) 60 (b) 61 (c) 62 (d) 63

Q3. A boy says, "I have many pencils. All of them are red except 3. All of them are green except 2. All of them are blue except 3". The total number of pencils the boy has is

(a) 4 (b) 5 (c) 6 (d) 8

Q4. If $a = \sqrt{3+\sqrt{3+\sqrt{3+\sqrt{3+...}}}}$, then the value of a is

(a) $\frac{1+\sqrt{12}}{2}$ (b) $\frac{1+\sqrt{13}}{2}$

(c) $\frac{1+\sqrt{7}}{2}$ (d) $\frac{1+\sqrt{11}}{2}$

Q5. The number of diagonals in a convex polygon with n-sides are:

(a) $\frac{n(n-3)}{2}$ (b) $(n-2)$

(c) $\frac{n(n-1)}{2}$ (d) $\frac{(n-1)(n-2)}{2}$

Q6. In a mall, a child runs fast on a moving platform from one end to the other, taking $2.5s$. Then she turns back and runs at the same speed on the moving platform to her starting point, taking $10s$. The ratio of the child's running speed to the platform's speed is

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

Q7. On earth a coconut falls on ground from a tree (of certain height) in 1 second. On a planet which has twice the mass of the earth (but same atmospheric conditions), the time (in seconds) taken by the coconut to fall on ground from the same height is

(a) 0.250 (b) 0.577 (c) 0.707 (d) 0.816

Q8. A vector $\vec{A}$ points vertically upward and vector $\vec{B}$ points towards north. Then the vector $\vec{A}\times\vec{B}$

(a) points towards west
(b) points towards east
(c) is zero
(d) points vertically downward

Q9. The solution of the differential equation $\log_e\left(\frac{dy}{dx}\right)=3x+4y$ (where c_1,c_2,c_3,c_4 are constants) is

(a) $4e^{3x}-3e^{-4y}=c_1$
(b) $3e^{-4y}+4e^{3x}=c_2$
(c) $4e^{4y}-3e^{-3x}=c_3$
(d) $3e^{-3x}+4e^{4y}=c_4$

Q10. Which of the following statements is true about the function $y=x^2-4$?

(a) The curve crosses x - axis at origin
(b) It crosses x - axis at a single, non-zero point
(c) It crosses x - axis at two points
(d) It does not cross x - axis at all

Q11. The product of the eigenvalues of the matrix e^A, where

$$A=\begin{pmatrix} a & 0 & 0 \\ 0 & 0 & b \\ 0 & b & -a \end{pmatrix} \text{ is}$$

(a) e^{2b}
(b) e^{a+b}
(c) e^{a-b}
(d) 1

Q12. There are two spherical soap bubbles A, B of radii R_1 and R_2 respectively such that R_1 is greater than R_2. If they are joined by connecting a narrow tube between them, then which of the following is true?

(a) The radius of A will increase and B will decrease until B disappears.
(b) The radius of B will increase and A will decrease until they are equal.
(c) The radius of B will increase and A will decrease until A disappears.
(d) The radius of A will increase and B will decrease until they are equal.

Q13. A person travels by train starting from a city A at 6.00 AM and reaches another city B (which is $240\,km$ away) at 10.00 AM. After waiting for half an hour he takes a bus and reaches another city C (which is $110\,km$ from B) at 1.00 PM. After a halt of 3.00 hours in city C he takes a train which takes him back to city A at 9.00 PM the same day. If the three cities lie along a straight line with B lying in between A and C, then the average speed of the round trip of the person is, approximately,

(a) $55.8\,km/hour$ (b) $60.9\,km/hour$ (c) $66.6\,km/hour$ (d) $69.7\,km/hour$

Q14. The work function for Ni is $4.1eV$. If light of wavelength $400\,\text{nm}$ is incident on Ni, which of the following statements is correct?

(a) There will be no emission of photoelectrons

(b) There will be emission of photoelectrons with no kinetic energy

(c) The emission of photoelectrons will depend upon the intensity of the incident light

(d) Photoelectrons will be emitted with a finite kinetic energy

Q15. The electric field of a light wave is given by

$$\vec{E} = \hat{x}E_0 \cos(\omega t - kz) + \hat{y}E_0 \cos\left(\omega t - kz + \frac{\pi}{2}\right)$$

where $\hat{x}$ and $\hat{y}$ denote unit vectors along x axis and y axis respectively. The above equation represents a

(a) linearly polarized light propagating in the z direction

(b) left circularly polarized light propagating in x direction

(c) elliptically polarized light propagating in the z direction

(d) right circularly polarized light propagating in z direction

Q16. A perfectly conducting and movable wall divides a container of gas into two systems so that the two systems can exchange energy. In equilibrium, which two physical quantities become equal on two sides of the wall?

(a) pressure and entropy (b) temperature and volume

(c) entropy and temperature (d) pressure and temperature

Q17. The number of all possible microstates, $\Omega(N,E,V)$ of an isolated system consisting of a classical ideal gas with total energy E is related to number of particles N and volume V as

(a) $\Omega \propto NV$ (b) $\Omega \propto V^N$ (c) $\Omega \propto N^V$ (d) $\Omega \propto e^{NV}$

Q18. Given that a piece of n-type silicon contains $8\times10^{21}\,m^{-3}$ phosphorus impurities atoms, calculate the carrier concentration at room temperature. Assume that the intrinsic electron concentration in silicon at room temperature is $1.6\times10^{16}\,m^{-3}$. The carrier concentration at room temperature is

(a) $1.5\times10^{8}\,m^{-3}$ (b) $5.8\times10^{10}\,m^{-3}$

(c) $7.0\times10^{12}\,m^{-3}$ (d) $3.2\times10^{10}\,m^{-3}$

Q19. The voltage gain of a Bipolar Junction Transistor amplifier drops at high frequency due to

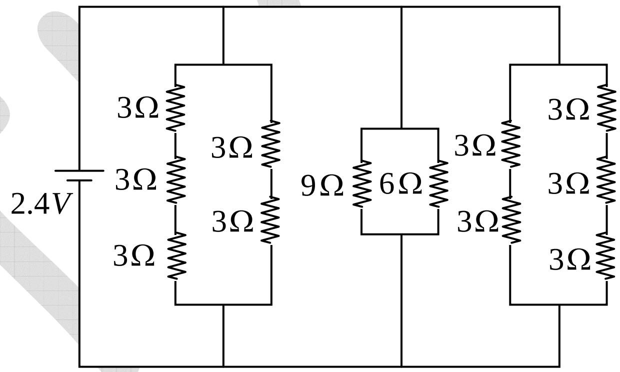
(a) the internal junction and coupling capacitors

(b) the coupling and bypass capacitors

(c) the stray-wiring and bypass capacitors

(d) the internal junction and stray-wiring capacitors

Q20. The amount of current flowing through the 6Ω resistor in the following network is



(a) $0.2A$ (b) $0.4A$ (c) $0.8A$ (d) $2.0A$

PART - B

Q21. The residue at the singularity of the complex function $f(z)=\frac{1-z}{(1-2z)^2}$ is

(a) $\frac{-1}{3}$ (b) $\frac{1}{3}$ (c) $\frac{1}{5}$ (d) $\frac{-1}{4}$

Q22. The Fourier Transform $g(\omega)$ of the function, $f(t)=e^{-\alpha|t|}$ (defined along the real line, where $\alpha>0$) is

(a) $\frac{1}{\sqrt{2\pi}}\frac{\alpha}{\alpha^2+\omega^2}$ (b) $\frac{1}{\sqrt{2\pi}}\frac{\alpha}{\alpha^2-\omega^2}$

(c) $\frac{1}{\sqrt{2\pi}}\frac{2\alpha}{\alpha^2+\omega^2}$ (d) $\frac{1}{\sqrt{2\pi}}\frac{2\alpha}{\alpha^2-\omega^2}$

Q23. Two relativistic particles are moving in free space along positive x-axis and negative x-axis with velocities $\vec{v}_1=v\hat{x}$ and $\vec{v}_2=-v\hat{x}$ respectively. The speed of one particle with respect to the other will be

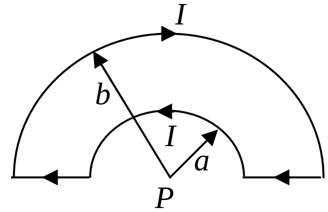
(a) 0 (b) $2v$ (c) $\frac{2v}{\left(1-\frac{v^2}{c^2}\right)}$ (d) $\frac{2v}{\left(1+\frac{v^2}{c^2}\right)}$

Q24. Three charges are located as follows: charge $+2q$ at $(0,a,a)$, charge $+q$ at $(0,-a,a)$ and charge $-q$ at $(0,0,-a)$ in a coordinate system with unit vectors $\hat{x},\hat{y}$ and $\hat{z}$. The dipole moment of this distribution is

(a) $\vec{p}=qa(\hat{y}+4\hat{z})$ (b) $\vec{p}=qa(\hat{x}+2\hat{y})$

(c) $\vec{p}=qa(\hat{y}+3\hat{z})$ (d) $\vec{p}=qa(2\hat{x}+4\hat{y})$

Q25. The magnitude of the magnetic field at the center point P, of the loop which carries a steady current I is



(a) $B=\frac{\mu_0 I}{4}\left(\frac{1}{a}-\frac{1}{b}\right)$ (b) $B=\frac{\mu_0 I}{2}\left(\frac{1}{b}-\frac{1}{a}\right)$

(c) $B=\frac{\mu_0 I}{8}\left(\frac{1}{b}-\frac{1}{a}\right)$ (d) $B=\frac{\mu_0 I}{2}\left(\frac{1}{a}-\frac{1}{b}\right)$

Q26. The electric and magnetic fields of an electromagnetic wave, in a given region of space is given by $\vec{E}(r,t) = \hat{y}E_0 e^{-kz}\cos(kx-\omega t)$ and $\vec{B}(r,t) = \hat{z}B_0 e^{-kz}\cos(kx-\omega t)$. The average value of the Poynting vector is given by

(a) $\langle S \rangle = \dfrac{E_0 B_0 e^{-2kz}}{2\mu_0}\hat{x}$ (b) $\langle S \rangle = \dfrac{-E_0 B_0 e^{-2kz}}{\mu_0}\hat{x}$

(c) $\langle S \rangle = 0$ (d) $\langle S \rangle = \dfrac{E_0 B_0 e^{-2kz}}{\mu_0}\hat{x}$

Q27. Two perfectly parallel He-Ne laser beams (of wavelength λ) from same source and separated by a distance $2d$ are focused by a lens of focal length, f. If $f >> 2d$, then the fringe width of the interference pattern formed at the intersection of the two beams is

(a) $\dfrac{d\lambda}{2f}$ (b) $\dfrac{2d\lambda}{f}$ (c) $\dfrac{f\lambda}{2d}$ (d) $\dfrac{2f\lambda}{d}$

Q28. Consider the Hamiltonian $H = \dfrac{p^2}{2m} + V(x)$ in usual notation, where

$$V(x) = \begin{cases} V_0 & for\, |x| < \dfrac{L}{2} \\ 0 & for\, |x| \geq \dfrac{L}{2} \end{cases}$$

In the limit $V_0 L =$ constant but $|V_0| \to \infty$ and $L \to 0$, which of the following is true?

(a) There is no bound state for both $V_0 \to \infty$ and $V_0 \to -\infty$

(b) There is one bound state for $V_0 \to -\infty$

(c) There are infinitely many bound states for $V_0 \to -\infty$

(d) There is one bound state for $V_0 \to \infty$

Q29. If $\hat{A}$ and $\hat{B}$ are two Hermitian operators which do not have common eigenvectors, then which of the following is true?

(a) $\left[\hat{A}, \hat{B}\right] = \hat{C}$, where $\hat{C}$ is a Hermitian operator

(b) $\left[\hat{A}, \hat{B}\right] = 0$

(c) $\left[\hat{A}, \hat{B}\right] = i\hat{C}$, where $\hat{C}$ is a Hermitian operator

(d) Information provided is insufficient to comment on the operator $\left[\hat{A}, \hat{B}\right]$

Q30. A particle of mass m is moving under the influence of a central force. If L_x, L_y are the x and y components respectively, of angular momentum and P_z is the z component of the linear momentum of the particle, then

$$\left[L_x,\left[L_y,P_z\right]\right]+\left[L_y,\left[P_z,L_x\right]\right] \text{ is}$$

(a) zero always

(b) need not always be zero

(c) never zero

(d) undetermined as the given information is insufficient to evaluate the sum of the commutators in question

Q31. Given $Q = aq + bp$ and $P = cq + dp$ and the transformation from (q, p) to (Q, P) is a canonical transformation, the condition satisfied by the constants a, b, c and d is

(a) $ad + bc = 1$ (b) $ad - bc = 1$ (c) $ac - bd = 1$ (d) $ac + bd = 1$

Q32. The Lagrangian for a mechanical system is given as $L = A\left(\frac{dx}{dt}\right)^2 - Bx^4$ where A and B are positive constants. The energy of this system is

(a) always zero (b) always positive

(c) always negative (d) need not be positive always

Q33. Which among these nuclei is the most stable: ${}^{12}_{6}C,\ {}^{17}_{8}O,\ {}^{41}_{20}Ca,\ {}^{208}_{82}Pb$?

(a) ${}^{12}_{6}C$ (b) ${}^{17}_{8}O$ (c) ${}^{41}_{20}Ca$ (d) ${}^{208}_{82}Pb$

Q34. Particle A with mass m_A at rest decays to particle B of rest mass m_B through $A \to B + \gamma$ transition. The (relativistic) energy of the outgoing particle B is

(a) $\frac{1}{2}m_A c^2$ (b) $\left(\frac{m_A^2 - m_B^2}{2m_A}\right)c^2$

(c) $\left(\frac{m_A^2 + m_B^2}{2m_A}\right)c^2$ (d) $\left(\frac{m_A + m_B}{2}\right)c^2$

Q35. A system is coupled to heat bath maintained at temperature T. The system has three energy levels E_a, E_b and E_c corresponding to energies $0; k_BT$ and $2k_BT$ respectively. The probability of finding the system in energy level E_a is

(a) 1

(b) $\frac{e^{-2}}{\left(1+e^{-1}+e^{-2}\right)}$

(c) $\frac{1}{e}$

(d) $\frac{e^{2}}{\left(1+e+e^{2}\right)}$

Q36. If C_p and C_v are molar specific heats at constant pressure and at constant volume for a gas respectively, which of the following statements is true about C_p and C_v. (R is universal gas constant)

(a) $C_p - C_v = R$ for any gas

(b) $C_p > C_v$ for any gas and $C_p - C_v = R$ for ideal gases

(c) $C_p > C_v$ for ideal gases but $C_p - C_v$ need not be R

(d) $C_p = C_v$ for ideal gases

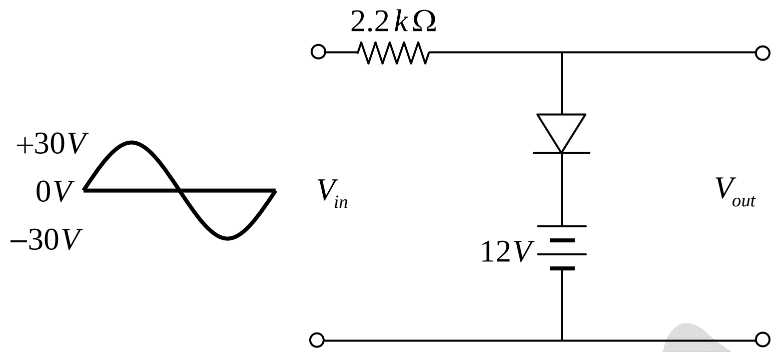
Q37. If energy (E) and Bloch momentum $(\hbar\vec{k})$ of a charge-carrier are related as $E = \frac{E_0\left[1-\cos(ka)\right]}{2}$ in one-dimensional lattice of lattice constant a (for $-\pi \le ka \le \pi$ and where E_0 is a constant), then the effective mass m^* of the charge carrier at $k \to \frac{\pi}{a}$ would be

(a) $\frac{-\hbar^2}{\left(E_0 a^2\right)}$ (b) $\frac{-2\hbar^2}{\left(E_0 a^2\right)}$ (c) $\frac{\hbar^2}{\left(E_0 a^2\right)}$ (d) $\frac{2\hbar^2}{\left(E_0 a^2\right)}$

Q38. X - ray of wavelength λ is reflected from crystal plane (220) of an fcc lattice with the Bragg angle 45^0 for the first order diffraction. Then the lattice parameter is

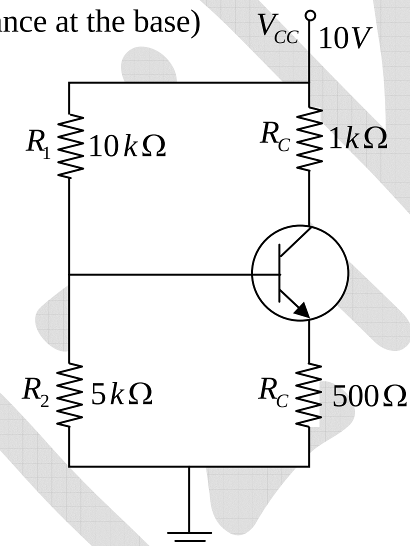
(a) λ (b) 2λ (c) 3λ (d) 4λ

Q39. The peak to peak voltage for the following circuit containing a Si - based diode is



(a) $17.3V$ (b) $29.3V$ (c) $42.7V$ (d) $47.0V$

Q40. The operating point (Q) of the npn transistor circuit shown below is (consider $\beta_{DC} = 100$ and neglect input resistance at the base)



(a) $(2.11V,\ 5.26\,mA)$ (b) $(8.20V,\ 1.20\,mA)$

(c) $(0.00V,\ 5.26\,mA)$ (d) $(2.11V,\ 0.00\,mA)$